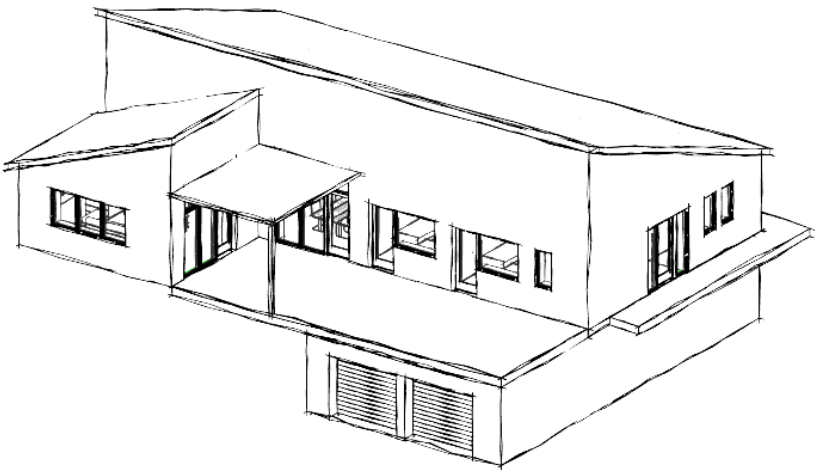
Bachelor Degree in Technical Architecture Spring 2015

CONSTRUCTIVE STUDY OF A DANISH SINGLE FAMILY SECOND HOUSE IN VILAFAMÉS. RENEWABLE ENERGIES, MATERIALS, CONSTRUCTIVE SOLUTIONS AND INSTALLATIONS.

FINAL PROJECT



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1. BACKGROUND

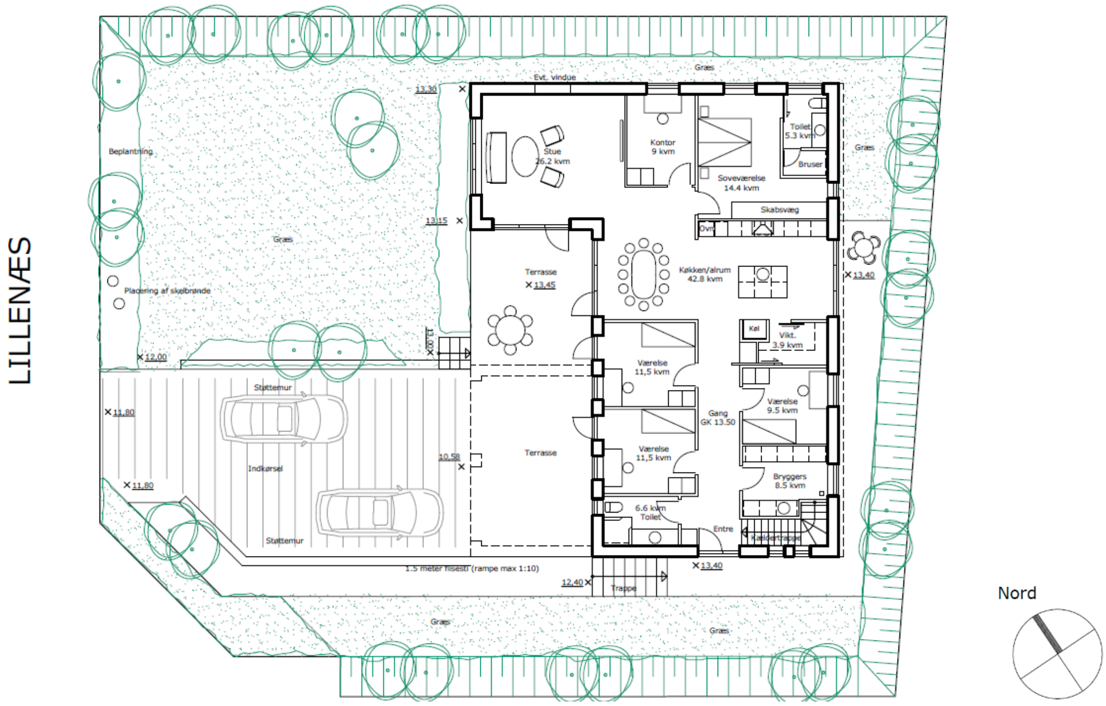
This project is a work made in two different universities: VIA University College, Denmark, and Universitat Jaume I UJI, Spain. Although in VIA these projects are made usually in groups, this one has been carried out individually due to the purpose of using it as a final project in UJI.

For that reason, I would like to thank both supervisors, Søren Alrø Skovbo in VIA and Juan Antonio García Espaza in UJI for all the guidance, help and advices I received from them during this year.

2. INTRODUCTION

The Danish family Jacobsen is a family of 4 members: both parents and 2 kids. They own a plot placed in Lillenæs 54, Snoghøj, Denmark, and they would like to build a new second house. It was on 2008 when they hired an architect who made the original project.

The house, of 189 m^2, consists on a big common space that includes the living room, the dining room and the kitchen. It also has four bedrooms, two bathrooms, an office, a laundry room and a storage room near the kitchen. Facing the garden, there is a terrace of 32 m^2. Near the main entrance there is a staircase which communicates the living area with the basement, which has space for two cars and working place and storage.



However they couldn't start the works so the house stays for some time just as a project. Was recently when they decided to build the house, but they are not sure where to place it because they still have the plot on Lillenæs 54 (758 m^2), but now they also own a plot placed in C/ Rei en Jaume I nº 17, Vilafamés (1291 m^2).

This project has the purpose of helping them to make this decission. For that, the energy behavior of the original project has been analyzed. After that, it is necessary to adapt the original project to the new Danish legislation, and then compare the changes with the Spanish current legislation. Is after this work when it is possible to see which placement is more convenient in order to have a low energy consumption house, so the Jacobsen family will be able to choose between both plots.

3. INITIAL INFORMATION

House placed in Denmark

Energy frame and Danish Building Regulations

As it has been mentioned before, the project was made in 2008, which means the regulations taken under consideration were BR08. This is important when analyzing the energy frame, because it has been changing during this years and each new regulation has a lower energy frame than the previous one. It is also important when analyzing the elements' properties: in the same way than the energy frame, the U-values of the elements have been becoming more restrictive.

The key values for knowing if the house is fulfilling the energy requirements are the *Energy performance framework* and the *transmission loss of building envelope elements*. This values will be the ones to reach and compare at the end of the analysis.

This project will need to fulfill the BR10, the current legislation, but in terms of energy consumption will be necessary to fulfills at least the guidelines for 2015 and try to reach the ones for 2020. However, it's also necessary to study the values of BR08 to know if the project was inside the minimums when it was designed.

Energy performance framework

The Danish Building regulation gives a formula to calculate this value, due to it depends on the m^2 of heated floor area. In the table below it can be seen the changes in this formula for the different regulations and the value needed, for the 189 m^2 of heated floor area.[1]

LEGISLATION	ENERGY PERFORMANCE FRAMEWORK	kWh / m^2 year
BR08	70 + (2200/A*)	81.64
BR10	52.5 + (1650/A)	61.23
BR2015	30 + (1000/A)	35.29
BR2020	20 + (1100/A)	20 [2]
*A = heated floor area (189 m^2)		

Transmission loss through building envelope elements

In the same way than the value explained before, the transmission loss through building envelope elements, excluding windows and doors, has been decreasing from one regulation to another. The next table shows the different values to be reached.

LEGISLATION	W/m^2
BR08	6
BR10	5
BR2015	4
BR2020	3.7

House placed in Spain

Spanish regulations

In this case, the house won't be analyzed again before the changes; that means the house under study to place it in Spain will be the one adapted to the new Danish Building Regulations.

For that, all the data and different parameters obtained when improving the house will be compared with the current Spanish legislation, Código Técnico de la Edificación also known as CTE, in his version of 2013 and will be used the specific document about energy savings HE.

For the installations, the last version of Reglamento de instalaciones térmicas en los edificios, RITE, will be consulted.

[1] Data from the different Danish Building regulations and BE10 Sbi-direction-213, second edition

[2] The formula gives a value of 25.82, but BE10 and specifications for 2015-2020 gives directly the value of 20 kWh/m^2 year

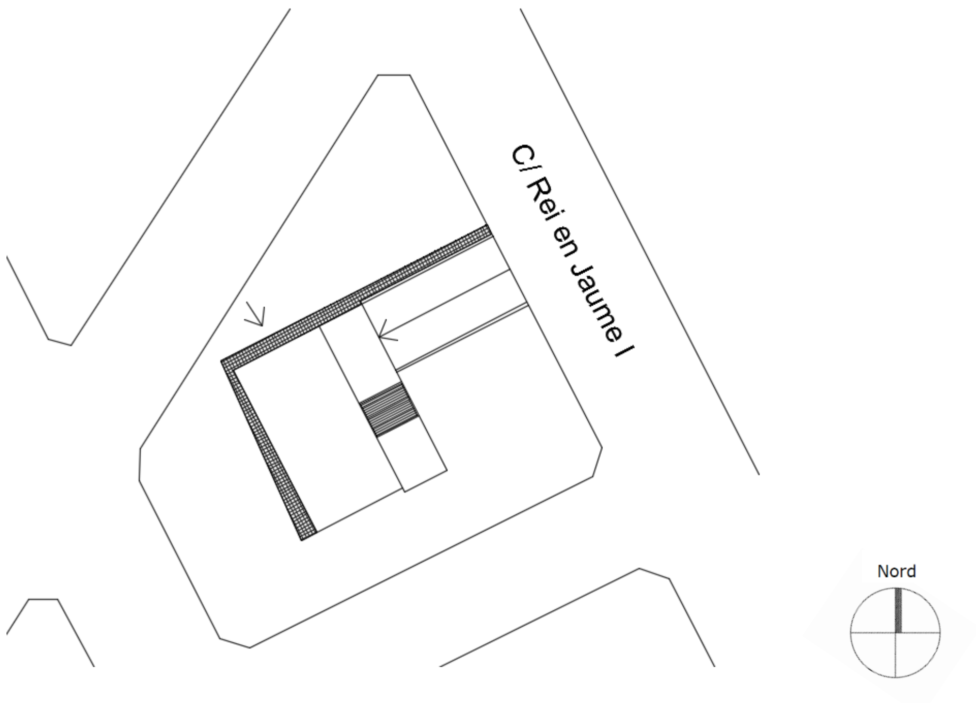
Orientation

One of the most important aspects to have a good energy behavior is the orientation the house will have. In the Denmark case, there were not many options about it, due to the plot was surrounded of other houses and there were just one access to it. However, in this case the plot is surrounded by streets, so the house can be placed in the optimal orientation, which is with the main entrance facing northwest, or 330º from North, that means is the completely opposite case than in Denmark.

This fact shows the differences between this two countries: while in Denmark is very important to face the most used spaces to the south in order to take profit to the sun, in Spain this orientation is bad for the summer months due to the excess of heat going inside the house.

The plot in Spain is located in C/ Rei en Jaume nº 17, Vilafamés, ant it consists of 1.291 m^2 completely surrounded by streets.

In the picture below can be seen the orientation chosen for the Spanish case.



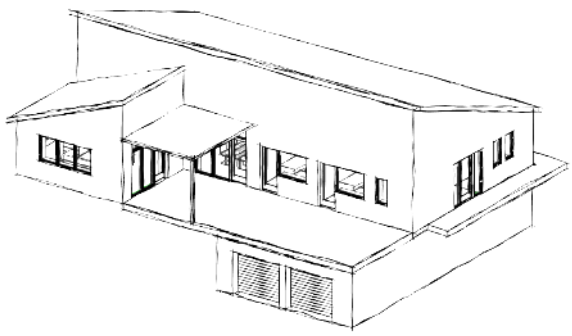
4. ORIGINAL PROJECT (BR08)

In this point are going to be described the elements conforming the building envelope and other components like windows and doors, in order to know their energy behavior and organized them in a clear way. Also a summary of the areas that will be needed for input in the simulation program in an easier way. Other analysis of this project are the installations and the indoor climate.

Building envelope elements

As can be seen in this 3D model of the building, the envelope has different heights. Is for that reason that from now, the building envelope elements and other components will be distinguished with the names of “Big” or “Small”, depending on which place of the building are they located. For the facades, they are going to be organized also depending on the orientation they have.

However, the building envelope is not corresponding exactly with the external elements. The heated area is only the living spaces of the ground floor, and the insulation is placed in the flat roof, creating an unheated attic between it and he pitched roof. It has different heights, so the external walls are different depending if they are involving the heated area or the unheated. To summarize, the building envelope is formed by: external walls until the flat roof, the flat roof and the ground floor.

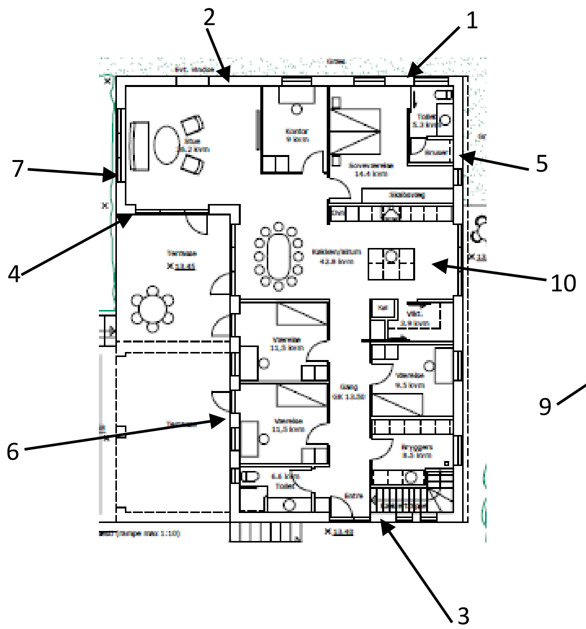


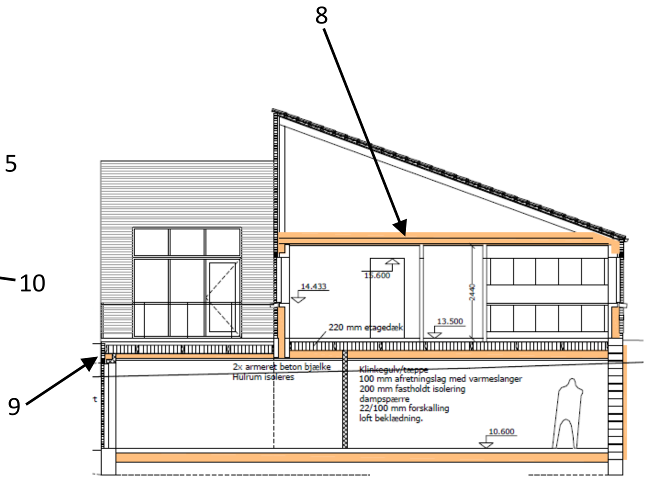
In the list below, information about the building envelope can be found, like the description of materials, location in the building and thickness of the layers.

<table>
<tr><th colspan="4">FACADES</th></tr>
<tr><th>Nº</th><th>Name</th><th>Layers (Thickness + Materials)</th><th>Total thickness</th></tr>
<tr><td>1</td><td>North façade-Big</td><td rowspan="7">(Outside)
108 mm – Bricks
190 mm – Insulation
120 mm – Lightweight concrete
(Inside)</td><td rowspan="7">418 mm</td></tr>
<tr><td>2</td><td>North façade-Small</td></tr>
<tr><td>3</td><td>South façade-Big</td></tr>
<tr><td>4</td><td>South façade-Small</td></tr>
<tr><td>5</td><td>East façade</td></tr>
<tr><td>6</td><td>West façade-Big</td></tr>
<tr><td>7</td><td>West façade-Small</td></tr>
</table>

FLAT ROOF			
Nº	**Name**	**Layers (Thickness + Materials)**	**Total thickness**
8	Flat roof	(Attic) 300 mm – Insulation 22 mm – Wood trusses (22 x 100) 20 mm – Plaster board (Inside)	342 mm

GROUND FLOOR			
Nº	**Name**	**Layers (Thickness + Materials)**	**Total thickness**
9	Ground floor-Contact with basement	(Inside) 20 mm – Cement tiles 120 mm – Concrete + Floor heating pipes 300 mm – Insulation 20 mm – Gypsum board/Cement screed (Outside)	460 mm
10	Ground floor-Contact with soil		





U-values

The project gave information about the different U-values of the building envelope elements and other components, but an additional calculation has been made to be sure about it, due to the lack of information about the method used to calculate them.

$$\frac{1}{U'} = Rsi + Rse + \sum_{i=1}^{n} Ri$$

The formula used to do this has been extracted from DS418, being U = U' + ΔU. However, the correction factor ΔU make reference to cracks in different layers, for that reason and because of the construction is new, it has been decided that the correction factor will be 0, so U' = U.

An example of a U-value calculation is going to be shown next, as well as a list of the other U-values.

Example of U-value calculation

EXTERNAL WALLS						
Layers	**Thickness (m)**	**Conductivity (W/mK)**	**Resistance (m2K/W)**	**U-value (W/m2K)**	**BR08**	**BR10**
Rsi			0,13	0,15	0,2	0,15
Lightweight concrete	0,12	0,15	0,80			
Rockwool	0,19	0,035	5,43			
Brick	0,108	0,9	0,12			
Rse			0,04			
Total	**0,418**		**6,52**			

To be able to calculate the U-value, the sum up of the resistances is needed. The internal and external resistance is known from the table 6.2.1 found in DS418, but for the other resistances the thickness of the material (d) and the conductivity (λ) are needed because R = d / λ. The λ value has been found in tables of DS418-Annex G, as well as from teacher slides of PAH-CS1 and ERE-CS1.

Table 6.2.1 – Surface resistance m2K/W

	The heat flow's direction		
	Upwards	Horizontal	Downwards
R_{si}	0,10	0,13	0,17
R_{se}	0,04	0,04	0,04

List of U-values

ELEMENT	U-VALUE (W/m²K)
External walls	0.15
Flat roof	0.1
Ground floor- Soil	0.10
Ground floor- Basement	0.11

Summary of areas

It is important to have information about the areas of each element, in order to be able to input this data later on into the BE10 simulation program. The program asks about the area of the building envelope elements with the area of windows and doors subtracted, which is calculated in the following point.

Nº	Name of element	Area (m²)
1	North façade-Big	21.16
2	North façade-Small	10.35
3	South façade-Big	21.16
4	South façade-Small	13.5
5	East façade	40.7
6	West façade-Big	29.74
7	West façade-Small	16.5
8	Flat roof	189
9	Ground floor-Soil	176.27
10	Ground floor-Basement	66.24

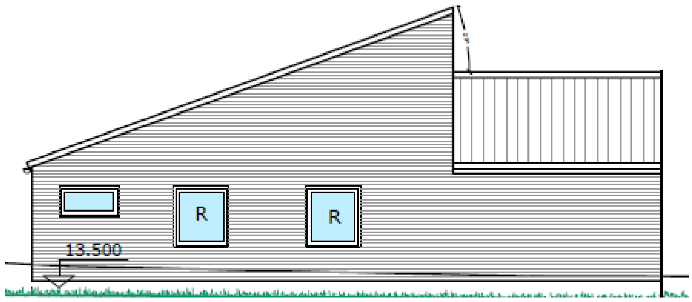
Windows and doors

The house have different windows and doors placed all around the facades. Even the U-value for all of them is the same, it is important to divide them into different types for later use, for example input them into BE10. For that, it's important to know the sizes of them and where are they located, because other parameters can influence them, as is the case of shadings.

In this case, the U-value is not going to be studied again. For glazed elements is important to know the energy behavior of the glass and the frame separately, and it can be very different depending on the manufacturer. For that reason it has been decided to take the value given by the project: 1.4 W/m^{2}K.

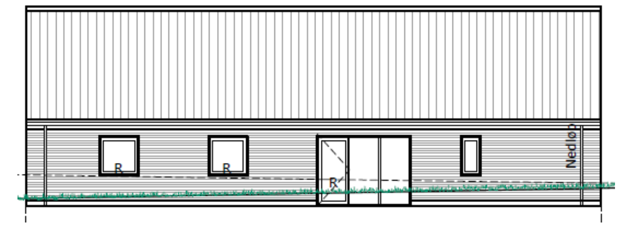
There are 7 different kind of windows and 1 type of glazed external door. The list below shows the information for all of them, and the drawings of the elevations shows where are they located.

ELEMENT	NAME	UNITS	WIDTH (m)	HEIGHT (m)	AREA (m^2)
Door	D	6	0.9	2.1	1.89
Window Type 1	W1	6	0.9	2.1	1.89
Window Type 2	W2	6	0.9	0.8	0.72
Window Type 3	W3	5	0.9	1.2	1.08
Window Type 4	W4	4	1.2	1.2	1.44
Window Type 5	W5	4	0.6	1.2	0.72
Window Type 6	W6	1	0.6	2.1	1.26
Window Type 7	W7	1	1.3	0.6	0.78



North façade. From left to right: W7, 2 x W4

South façade.
Small façade. From left to right, below: 2 x W1, D.
Small façade, above: 3 x W2
Big façade. From left to right: D, W6, 2 x W5



East façade. From left to right: 2 x W4, D, 2 x W1, W5

West façade.
Small façade: 3 x W3
Big façade. From left to right, below: 2 x W1, 2 x D, W3, D, W3, W5
Big façade. From left to right, above: 3 x W2

Installations

There is not much information about the installations for this project, so the information described below are assumptions from the information found in the plans and the common practice of building houses at the time the project was made.

Heating system

Is stated in the project that the heating will be supplied by floor heating. The system is already integrated in the concrete layer of the ground floor, and it's installed in all the rooms of the living area, including the storage and the laundry room.

The floor heating takes the heated water from the district heating that supplies the water to the distribution tanks placed in the laundry room, and supplies it at an initial temperature of 55 º C. From there, the distribution of the pipes consists of supply and return pipes, from where other secondary pipes distribute the water to the different rooms. Each room should have its own loop, so it is possible to regulate the temperature individually.

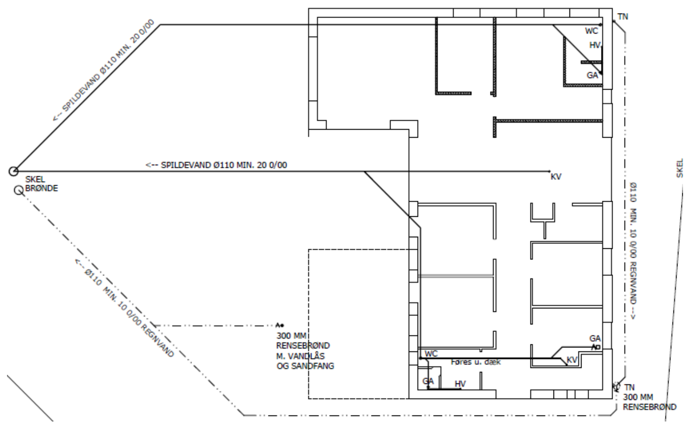
The return pipes goes to the return tank, placed with the distribution one, and is connected to the district heating return pipe at the street.

Domestic Hot Water supply system

The DHW system consists on a water tank placed in the storage room. This tank takes the water from the Domestic water supply pipe from the street. To heat this water a closed circuit inside the tank takes the warm water from the district heating pipes. The supply of the Domestic cold water is taken directly from the supply pipes.

Sewer system

The sewer system is described in the plans of the project, and it consists on different drains placed at the bathrooms, kitchen and laundry room, that join in a single pipe connected to the waste water pipe at the street. A separate system collect the rain water and connect it to a different waste water pipe.



Ventilation system

The ventilation system has been stated in the project as natural ventilation. This means that the supply of fresh air is reached by opening the windows. There is an extract diffuser in the kitchen through the cooking hood, and valves in the bathrooms to allow an exchange of air in this rooms, but even with these appliances, the system is considered by the BR10 as natural ventilation.

Indoor environment

To be able to check the quality of a modern house it's important to take into account not only the energy behavior but also a good indoor environment, which will ensure a comfortable live of the family living inside it. But they are not independent parameters: indoor environment has a direct effect also in the energy consumption of the house, so a good planning is necessary to lower this consumption. The parameters are studied in different fields, like thermal indoor climate, atmospheric indoor climate or visual indoor climate.

Thermal indoor climate

According BE10-Sbi directions and DS418, the internal temperatures are stated at 20º C. Temperatures between 25 and 27 ºC decreases the productivity of people about a 30%. For that reason temperatures between this ranges are considered as overheating. In the 2015-2020 specifications, can be found the limits for the overheating: a temperature of 26ºC can't be reached more than 100 h per year, and a temperature of 27ºC is limited by 25 h per year. The thermal indoor climate is controlled by the heating and ventilation systems of the house.[3]

Atmospheric indoor climate

A good atmospheric indoor climate is reached thanks to a good ventilation system that removes the internal polluted air and supplies fresh air. In that way, the amount of CO_2 can be decreased, as well as other pollutants, and with a good ventilation system is also possible to control the humidity, so the appearance of dust mites or fungi is more difficult with good air quality and low humidity rates. In this case is not possible to have a control of the air quality due to the ventilation is natural.

Visual indoor climate

The visual indoor climate is referred to the amount of light that exists in the rooms, but most important of it, the amount of natural light. According BR10, there are minimums about the percentage of glazed area in a room depending on its surface that should be fulfilled, and also a parameter known as Daylight Factor, up to 2%, should be present in the rooms. The places that don't reach this DF should supply extra light from electrical appliances.

[3] The overheating will be calculated with the BE10, in a following point

Glazed area

In the table below can be seen the calculation of glazed area percentage for each space of the living area of the house.

ROOM	AREA (m^2)	10% OF THE AREA (m^2)	WINDOWS	AREA OF THE WINDOWS (m^2)	FULFILLS?
Living room	23	2.3	3 x W1, 2 x W1, 3 x W2, D	11.07	YES
Dining room	16	1.6	3 x W2, 2 x W1, 2 x D	9.72	YES
Kitchen	21	2.1	2 x W1, D	5.67	YES
Main bedroom	16	1.6	W4, W5	2.16	YES
Main bathroom	4.3	0.43	W7	0.78	YES
Bedrooms 1-2	9.3	0.93	W3, D	2.97	YES
Bedroom 3	8.8	0.88	W4	1.44	YES
Laundry room	7.3	0.73	W4	1.44	YES

Daylight Factor

To know the daylight factor in each room of the house it has been necessary to do a simulation with VELUX Daylight visualizer. The simulation gives information for a cloudy day in January, which is considered the worst lighting situation of the year.

In the simulation can be seen that the minimum 2% of daylight factor is reached only in a delimited area of the kitchen, dining room and living room, going in this room up to a 3% in the south corner. However, the minimum is not reached in any of the other rooms, and this can be a problem, especially in the office and the bedrooms, where activities like reading or studying take place there. This result means that, even the minimum glazed area is reached, this is not enough for the amount of light needed, so some changes on the windows will be needed to be applied, always taking into account that an increase of glazed area can also means an increase of overheating.

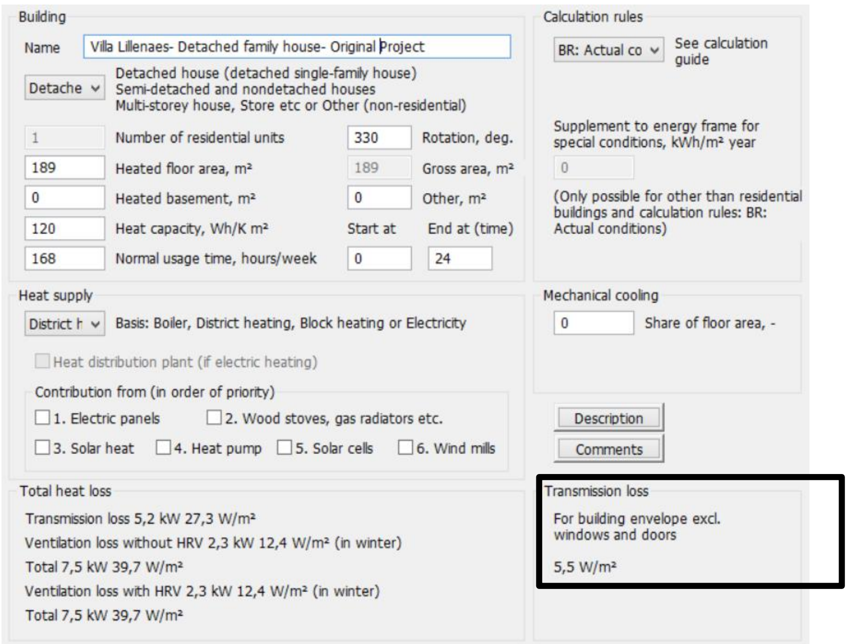
Simulation with BE10

In order to know the energy behavior of the house taking into account all the elements of the building envelope, as well as windows and doors and the installations, it is necessary to develop a simulation with BE10, which studies the building following Danish Building Regulations.

The program is organized in different sections where the data studied should be input, and in this case, the ones that are going to be used are the initial information, building envelope, unheated rooms, overheating, ventilation, heating and DHW installations and the final result. Just some examples are going to be shown in the following points.[4]

Initial information

The picture shows the information of the building, as the rotation of the house and the heated floor area (information extracted from the project) or the heating capacity of the building elements, information that can be found in the table 8 of the Sbi-directions, second edition. The value of 120 Wh/K m^2 is referred to medium heavy constructive elements.



Other information that can be extracted from this view is the Transmission loss for building envelope elements. This value is shown once the information about the building envelope is input in the program. As it has been stated in point 3. Initial information, this transmission loss should be equal or less than 6, 5, 4 and 3.7 W/m^2 for BR08, BR10, 2015 and 2020 specifications, respectively. From the value calculated by the program, the building just fulfills the Transmission loss required by BR08.

[4] See Annex A.2 for further information of BE10 results

Building envelope

In this point is where the data summarized before should be inserted, as are the areas of the elements and its respective U-values. Also the design temperatures are needed, and they can be found in DS418.

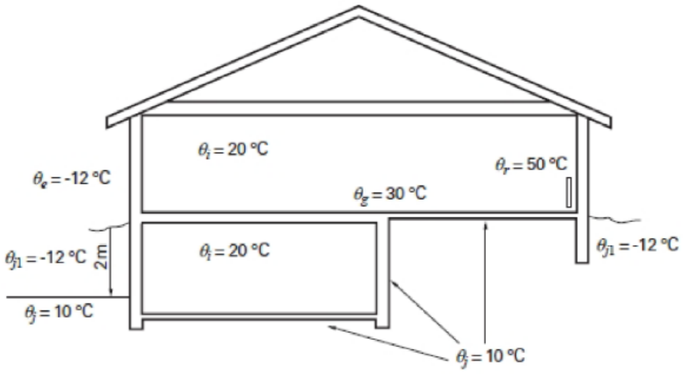


Figure 2.1 – Examples of design temperatures

External walls, roof and floor

Information about the facades is input in the tables: Areas, U-values and the temperatures. The temperature factor is stated as 1 following the instructions found in Sbi-directions, and with all this information the program calculates the Specific transmission loss (Ht) and the Design transmission loss. In the picture below can be seen an example of external wall:

	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		46,24		CtrlClick	9,248			295,936
1	West facade-Small	16,5	0,2	1,00	3,3	20	-12	105,6
2	West facade- Slab height 1	19,7	0,2	1,00	3,94	20	-12	126,08
3	West facade- Slab height 2	10,04	0,2	1,00	2,008	20	-12	64,256

For the calculation of the slab, the same considerations as in the external walls are made, and for the temperatures, it has been considered also 20ºC inside and -12ºC outside. This consideration about the outside temperature is because even it is in contact with the attic, this space is unheated and assumed partially ventilated, so the temperature will be the same as the outdoor air.

	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		189		CtrlClick	15,876			725,76
1	Flat roof-Slab	189	0,12	0,70	15,876	20	-12	725,76

In relation with the ground floor, it has been divided in two calculations depending if it is in contact with the soil or with the basement air. The U-value for the floor changes for each one, due to the external resistance each external material (air or soil) has. Moreover, the temperatures change as well. The external temperature of the soil is 10ºC according to the picture of DS418 shown above, but what changes is the temperature of the basement. Even it can be assumed that there can be some leakages of air through the basement doors, this is not going to make that high difference to be able to consider it -12ºC. However, the basement is still an unheated room, so neither 20ºC are acceptable. For these reasons the temperature of the basement is stated at -5ºC.

	External walls, roofs and floors	Area (m²)	U (W/m²K)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		242,51		CtrlClick	24,0265			786,07
1	Floor-Basement	66,24	0,1	0,70	4,6368	20	-5	165,6
2	Floor-Soil	176,27	0,11	1,00	19,3897	20	-12	620,47

Furthermore, and again following Sbi-directions, the temperature factor for the floor in contact with the basement is stated at 0.7, because this element fits the description of being a building component sited against an unheated room, and the same happens with the flat roof shown above.

Foundations and joints between windows and doors and externals walls

In this tables is stated the length of the elements that can become a thermal bridge. These are the connections between the foundations and the walls, and the ones from the windows and doors with the walls.

Table of linear losses	Linear loss W/mK
Foundations around rooms/ spaces that are heated to a minimum of 5°C.	0.40
Foundations around floors with underfloor heating.	0.20
Joint between external wall and windows or external doors and hatches.	0.06
Joint between roof structure and rooflights or skylight domes.	0.20

In the same way than the external walls, the length, temperature factor and temperatures are input, and the program calculates the Specific transmission loss and the design transmission loss. In this case, however, is also needed the linear loss. For that reason the maximum accepted value for this linear loss has been assumed, according BR10- 7.6, Minimum thermal insulation.

	Foundations and joints at windows	l (m)	Loss (W/mK)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		76,6		CtrlClick	15,32			490,24
1	Foundations	76,6	0,2	1,00	15,32	20	-12	490,24

In the same way it has been calculated the joints around windows and doors, calculating the total perimeter in contact with the walls and applying a temperature factor of 1, as well as the indoor and outdoor temperature. Like the foundations, the linear loss applied is the one extracted from the table of the BR10.

	Foundations and joints at windows	l (m)	Loss (W/mK)	b	Ht (W/K)	Dim.Insi	Dim.Out	Loss (W)
		156,2		CtrlClick	9,372			299,904
1	Joints door	36	0,06	1,00	2,16	20	-12	69,12
2	Joints Wind. 1	36	0,06	1,00	2,16	20	-12	69,12
3	Joints Wind. 2	20,4	0,06	1,00	1,224	20	-12	39,168
4	Joints Wind. 3	21	0,06	1,00	1,26	20	-12	40,32
5	Joints Wind. 4	19,2	0,06	1,00	1,152	20	-12	36,864
6	Joints Wind. 5	14,4	0,06	1,00	0,864	20	-12	27,648
7	Joints Wind. 6	5,4	0,06	1,00	0,324	20	-12	10,368
8	Joints Wind. 7	3,8	0,06	1,00	0,228	20	-12	7,296

Windows and outer walls

In this part of the building envelope study, every window and door should be analyzed. Is here where can be seen the importance of define each window according its location in the house and the type of window, because a lot of parameters can influence them separately.

	Windows and outer doors	Num	Orient	Inclina	Area (m²	U (W/m²k	b	Ht (W/K)	Ff (-)	g (-)	Shadir	Fc (-)	Dim.Ir	Dim.O	Loss (W)	Ext
		10			12,42		CtrlCli	17,388			CtrlCli				556,416	0/1
1	South (Small) Door	1	S	90	1,89	1,4	1,00	2,646	0,6	0,63	South	0,8	20	-12	84,672	1
2	South Door	1	S	90	1,89	1,4	1,00	2,646	0,6	0,63	South	0,8	20	-12	84,672	0
3	South Window 1	2	S	90	1,89	1,4	1,00	5,292	0,8	0,63	Souh	0,8	20	-12	169,344	1
4	South Window 2	3	S	90	0,72	1,4	1,00	3,024	0,7	0,63	South	0,8	20	-12	96,768	1
5	South Window 5	2	S	90	0,72	1,4	1,00	2,016	0,5	0,63	South	0,8	20	-12	64,512	0
6	South Window 6	1	S	90	1,26	1,4	1,00	1,764	0,8	0,63	South	0,8	20	-12	56,448	0

In this example can be seen the values asked by the program to calculate the influence of the windows in the total energy behavior of the building.

The first parameters are: the units of each type that can be calculated together, its orientation, the inclination from the horizontal plane, area of each type and U-value. Like some of the other elements explained, the temperature factor is stated at 1, and also the temperatures of 20ºC inside and -12ºC outside.

For the other parameters, like the glazing part, the pane's solar transmittance or the solar screening, the instructions of Sbi-directions have been followed.

For example, the glazing part depends on how much glass there is as a percentage in relation with the total area of the window. The guideline give a range comprehended between 0.5 and 0.8, being 0.5 less glazed area and 0.8 a bigger percentage of glass. Depending on each type of window, an approximate value inside this range has been assigned to them.

In the case of the g-value, as the same happens with the U-value, there is no more information from the manufacturer, so also an approximated value should be applied. In this case, the average of the range for the specific type of window.

Table 11 Typical solar transmittance, g, for different pane types. The solar transmittance is for the solar radiation perpendicular to the glass.

Pane type	Solar transmittance
1-layer of clear glass	0,85
2-layers of clear glass	0,75
3-layers of clear glass	0,65
2-layers of energy pane	0,60 – 0,65
3-layers of energy pane	0,50 – 0,55
Solar screening glass	0,25 – 0,50

Regarding the solar screening, it has been assumed that curtains, manually controlled are installed in every window. The value to apply for this assumption is 0.8, given by Sbi-direction.

The last column allows to select the windows placed in a specific room to do an overheating study. The space selected is the common area conformed by the living room, the dining room and the kitchen, but will be explained in a point explained below.

Shadows

The column for shadows in the calculation of the windows is associated to the deep calculation of shadows in the corresponding tables.

	Shading	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening
1	South (Small) Door	15	0	83	0	5,5
2	Souh (Small) Window 1	15	0	77	0	5,5
3	South (Small) Window 2	15	0	79	0	5,5
4	South Door	15	0	0	0	5,5
5	South Window 5	18	0	0	0	8,3
6	South Window 6	15	0	0	0	8,3

5 different parameter influencing the shadings are asked by the program, but not all of them are present at the same time.

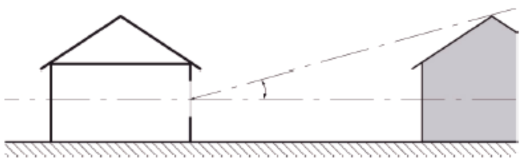
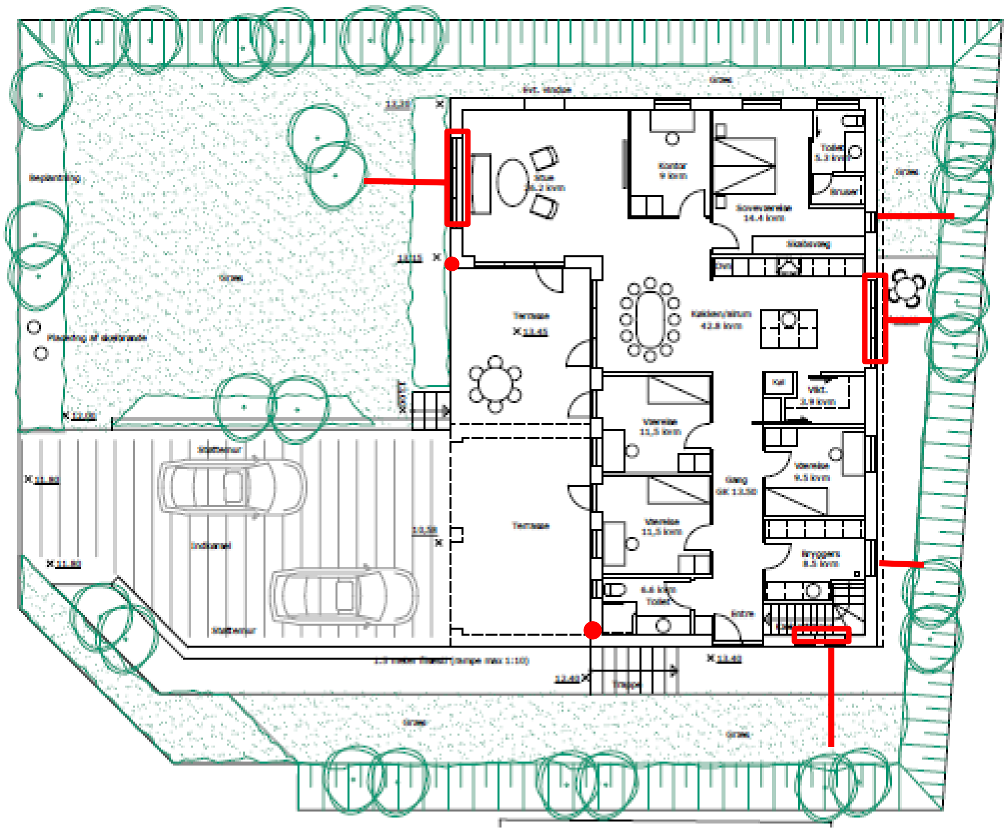


Figure 2 Determining of horizon angle

This figure from Sbi determines the way to calculate the horizontal angle. There is always an angle of 15º, which is approximately the angle of the sunlight, but can be bigger if some object is obstructing this incident sunlight.

There is no information about the buildings that surround the plot, but some trees have been placed in the plot that can have an effect on the windows. The plan shows which windows are affected by them.

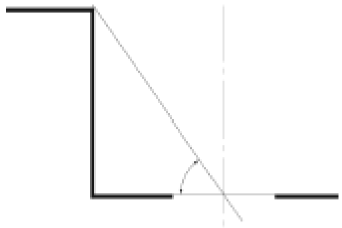


Below can be found a summary table showing every horizontal angle different than 15º which can be found in the project.

Element	Horizon (º)
South Big façade- W5	18
East façade- D, W1, W5	31
East façade- W4	45
West Small façade- W3	23

In this case, there are no eaves in the roof, so the second column will remain at 0. But some of the windows have right or left shadows, as is the case of the ones placed facing the terrace.

Figure 4. Determining of angle to the right respectively left. (Horizontal plan)



In the table example of shadow's calculation with BE10, the calculated windows are the ones placed in the south façade. For this reason, the windows of the small façade have shadows to the left. For the same type of window, it has been assumed that they are the same window (instead of 3 W2, one larger window) so the angle obtained is an average calculation for each type.

The points that can through shadows to the right and left are marked in the plan above in red. In the table below can be seen a summary table for the right shadow and another for the left.

Element	Right (º)
West Big façade- D	59.5
West Big façade- W1	73.85
West Big façade- W2	69
West Big façade- W3	32.5
West Big façade- W5	24

Element	Left (º)
South Small façade- D	83
South Small façade- W1	77
South Small façade- W2	79

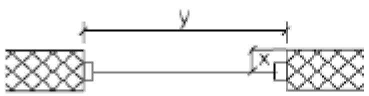


Figure 5. The window recess in percent is determined as x/y.

In the case of the window recess, due to the way they are installed in the external wall, every type of window have window recess. It depends, as is shown in the picture, on the width of each window and the deep they are installed in the wall. Here are listed the values for each one of them.

Element	D	W1	W2	W3	W4	W5	W6	W7
Recess	5.5	5.5	5.5	5.5	4.2	8.3	8.3	3.8

Unheated rooms

I this table the information input is related to the rooms that are placed outside the building envelope, but are in contact with it, so there is a heat flow between them.

As can be seen in the following calculation table from the BE10, the data to input is the total area of the unheated room and its ventilation minimum airflow. The first table is related to the element that connects the building with the unheated room, through which there is a heat loss from inside the building envelope. The second table refers to the heat loss through the building components of the room under study. In both cases, the program calculates the heat loss using the area of the elements and it's U-value.

Unheated room		Ventilation loss		Heat balance
Name	Gross area (m²)	Vent (l/s m²)	Heat loss (W/K)	Hi 6,5 W/K
Basement	93,8	0,3	34,0494	Hu 202,3 W/K
				Temp factor 0,969

	Building component	Area (m²)	U (W/m²K)	Ht (W/K)
	Transmission loss from building			6,48
+1	Floor	64,8	0,1	6,48
2				
3				
4				
5				
6				
7				
8				

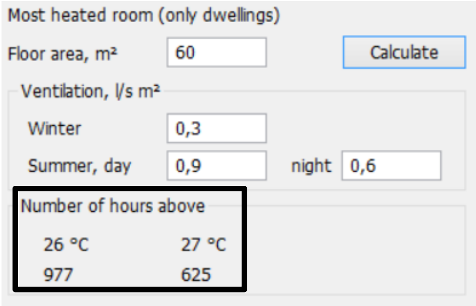
	Building component	Area (m²)	U (W/m²K)	Ht (W/K)
	Transmission loss to surroundings			168,218
+1	Basement walls-Soil	96,88	1,22	118,194
2	Terrace floor	33,84	0,1	3,384
3	Floor	93,8	0,11	10,318
4	Doors	9,68	1,4	13,552
5	Basement wall-Ramp	9,9	2,3	22,77

Overheating

This part of the calculation, also called "summer comfort", studies the overheating in one room of the house. To do that, the area of this room is needed, as well as its minimum airflow for winter and for summer. The program takes the information about the chosen windows from the tables where they are calculated.

In this case the room chosen to study has been the common area, which includes the living room, dining room and kitchen. It has been selected this specific area of the house due to is where the most part of the time during the day is going to be spent, and is also the one with more openings.

As can be seen in this picture, the area of the common space is up to 60 m^2, and the airflow for the ventilation in winter is stated to 0.3 $l/s/m^2$.[5] The values of airflows for summer are considered as an average assuming that in this period of time, the windows remains opened and the flow of fresh air increases. The numbers below shows the amount of hours during a year when the temperatures of 26ºC and 27ºC are going to be risen. As it has been explained in Indoor environment point, the temperature of 26ºC can be risen no more than 100h per year, while 27ºC has a maximum of 25h per year. The numbers obtained are far away from the maximum limits, which means that some solutions like increasing shadings should be taken.



Ventilation

In this point the program starts asking for information about the installations of the building, which also consume energy or, as in the case of the ventilation, becomes another way from where can be heat loss. As the original system of the house has been natural ventilation, the only parameters to include in the table are the working time, the airflow for winter and the airflow for summer.

Due to the building is a dwelling, the working time is stated at 1, because is considered in use the 24h per day every day. The airflow for summer, also used for the calculation of the overheating, is extracted from the guidelines, which makes this consideration:

> In dwellings and the like with manually controlled windows it can at most be accepted that the windows can be left open 75 % of time. It can normally be assumed a ventilation of 0,9 litres/sec. per m^2 heated floor area as an average warm summer periods.

On the other hand, the airflow for winter is dimensioned following the BR10 regulation. In the point 6.3 Air quality, minimum airflows for ventilation in different buildings are shown. For the case of dwellings, the airflow for supply is minimum 0.3 $l/s/m^2$, but there should be a balance between supply and extraction, and the airflows for extraction are 15 l/s for bathrooms and 20 l/s for kitchens. With this data, the airflows remains like explained below:

[5] The value is the minimum requirement from the BR10, 6.3. Air quality.

Extraction	Kitchen	Bathroom	Main Bathroom	Total
	20	15	15	50
Supply	Airflow	Heated floor area[6]		Total
	0.3	157.3		47.2

There is a difference between extraction and supply airflows, so there is a need to increase the supply until 0.32 l/s/m2 to be able to have the balance.

	Ventilation	Area (m	Fo, -	qm (l/s	n vgv (-)	ti (°C	El-H	qn (l/s r	qi,n (l/s	SEL (kJ	qm,s (l/	qn,s (l/s	qm,n (l/	qn,n (l/s
	Zone	189		Winter			0/1	Winter	Winter		Summe	Summe	Night	Night
1	Dwelling	189	1	0	0	0	0	0,32	0	0	0	0,9	0	0

Even has been necessary to reduce the area in the table of dimensioning, in order to know the proper amount of supply air, in BE10 the total heated floor area of the building is input, due to the table of ventilation is designed to calculate both, supply and extract air.

Internal heat supply

This part assumes that there is some internal gains from people living inside the building and from the appliances and electrical devices that release some heat to the inside. The data input are average values found in Sbi-directions.

	Internal heat supply	Area (m²)	Persons (W/m²)	App. (W/m²)	App.night (W/m²)
	Zone	189,0	283,5 W	661,5 W	0,0 W
1	Dwelling	189	1,5	3,5	0

Heat distribution plant

The heating system is explained in this tables, and first of all, the type of system is described as dual (1 supply pipe from where other distribution pipes take the water, and 1 return pipe where the return water of every room has gone there). Also the temperatures are stated here, 55ºC and 25ºC for supply and return, respectively. These are normal temperatures when referring to floor heating.

[6] The area is different than the Gross area of the building due to the extraction zones' area has been subtracted.

Heat distribution plant

Composition and temperature

Description	Dimensioning	
Supply pipe	55	Supply pipe temperature, °C (at outdoor temp. of -12 °C)
Return pipe	25	Return pipe temperature, °C
	2	Type of plant: 1: unified or 2: dual

In the second table to describe the system, the length and loss of the pipes are input, and if the system is placed inside the building envelope (b=0) or outside it (b=1). It's important to take into account that this pipes are the main pipes, the ones from where the supply pipe for each room takes the heat. Due to the floor heating haven't been dimensioned, it has been assumed that the length of the main pipes is equal to the length of the building. The value input is this length multiplied by 2, to have both supply and return.

Heating pipes

The statement includes pipes without outdoor temp. compensation and pipes beyond the heated part of the building.

	Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor coı	Unused sur
		33				
1	Floor heating pipes	33	0,3	0	J	J

Due to the length of the main pipes, it is necessary to have circulation pumps to allow the good flow of water, so they are calculated in the next table in BE10 and summarized like is shown in the picture.

Pumps

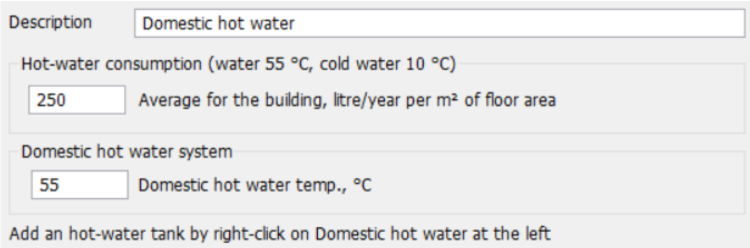
Pump installation

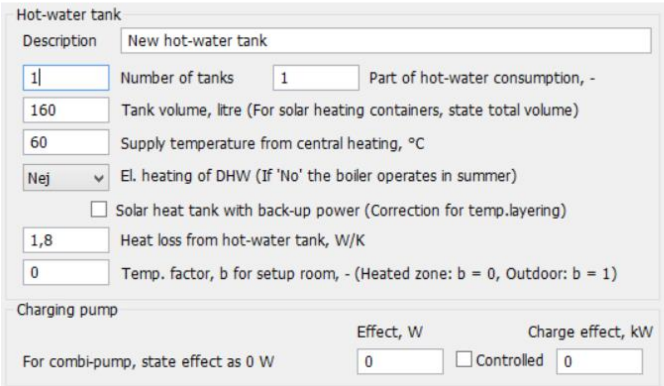
Number	Pnom, W	Fp, -	
0	0	0	(A) Constant service all year
0	0	0	(V) Constant service in heating season
0	0	0	(T) Time-controlled service in heating season
2	90	0,6	(K) Combi-pump (const. in heating season)

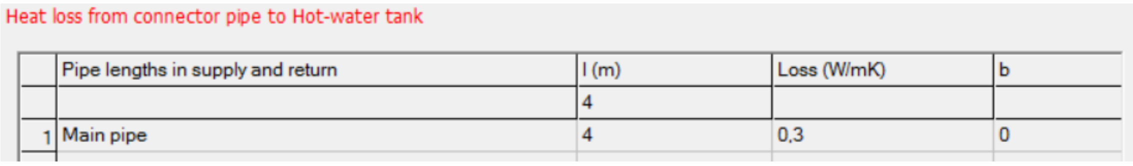
Domestic hot water

The initial information about the DHW system are average values given by the program, as normal values for this kind of system.

The system needs also a water tank, so it's added in a separate table, and information about the volume, the temperature inside it and the heat loss are stated, with average values for this data. Also is needed the supply pipe's length with its heat loss, and in this case, the addition of circulation pipes has not been necessary due to the distribution pipes are less than 9m, and this distance is considered not that long to need circulation pumps.






Heat loss from connector pipe to Hot-water tank

	Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
		4		
1	Main pipe	4	0,3	0

Results

At the end of the calculation there is a table that gives the values for the energy performance framework of the different Building regulations and also some information about the energy used for different purposes, which can be useful in order to know which improvements are needed to be applied.

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
61,2	0,0	61,2
Total energy requirement		90,1

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
35,3	0,0	35,3
Total energy requirement		74,1

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		56,1

Contribution to energy requirement		Net requirement	
Heat	80,0	Room heating	59,4
El. for operation of bulding	2,7	Domestic hot water	18,0
Excessive in rooms	3,2	Cooling	0,0

Selected electricity requirements	
Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	0,0
Pumps	2,5
Cooling	0,0
Total el. consumption	33,4

Heat loss from installations	
Room heating	2,6
Domestic hot water	4,9

Output from special sources	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

It can be appreciate that any of the energy performance framework is achieved. This is understandable because the project was made in 2008 and any of the regulations analyzed here where a requirement. However, if the value obtained for BR10, 90.1 kWh/m^2 year is compared with the requirement extracted from BR08 and stated in the first point if this report, 81.64 kWh/m^2, can be seen that neither the regulation that should have been fulfilled at the time of the project reached the parameter required.

Conclusion

From the data obtained, is clear that a huge amount of energy is spent in heating up the house. To reduce this amount of energy, one solution could be the improvement of the building envelope elements, increasing the insulation and making the entire building more airtight.

Another possible solution to reduce the energy is to implement renewable energy systems in the house, as any is installed now, so no extra energy is gained from them.

In the case of the overheating studied before, it should be reduced as much as it is possible with solutions like increasing the shadings, but at the same time, the Daylight factor has to be risen, so this will be a challenge in order to obtain the best result for both parameters.

On the other hand, neither the design transmission loss for building envelope elements is fulfilled, as the program calculates a value of 5.5 W/m^2, so is deduced also from this value that there should be an improvement in the building envelope elements.

5. CONSTRUCTIVE SOLUTIONS IMPLEMENTATION (BR10-CTE2013)

After the energy calculation of the Original project, several changes are needed to be applied in order to reduce the values of the Design transmission loss through building envelope elements and the Energy performance framework.

After this point, just the building is going to be analyzed due to no changes are going to be applied in the plot, and the shadings in the windows from the trees in the garden will be the same. The same points than the analyzed for the original project will be explained, showing which changes have been considered and which ones have been finally chosen and for what reasons.

After applying this changes, they will be compared to the requirements of the Spanish regulations in order to see if they are enough to fulfill them or need to be changed.

Building envelope

The elements of the building envelope are ones of the most important elements to be improved, due to the tighter the building is, the less amount of heat is lost. The improvements study the total U-values of the options proposed and also the approximated price[7]. However, the building envelope elements are ones with the most influence in the total energy behavior of the building, so the U-value will have more importance at the time of choosing an option than the price, due to the purpose of the project is to improve the building to a low energy consumption house.

Otherwise it has been taken into account not just the building envelope but also the installations that are going to be installed. The reason is that the building envelope influence on them: for example the ventilation system that is going to be included has a better performance if it is placed inside the building envelope, having less losses. For this reason, it has been decided that the building envelope will be changed, having the insulation not in the flat roof inside the building but in the pitched roof because of the ventilation unit, that is going to be placed in the attic.

To sum up, the building envelope has been changed and comprehends the following elements: Ground floor, entire external walls and pitched roof. With this new building envelope in mind, different options have been considered for each element. As it is a new proposal, the thicknesses of the elements can be different from the original project.

[7] As the project improved takes into account the Danish building regulations, the prices will be in Danish currency.

Denmark

Options studied

EXTERNAL WALLS				
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price[8]**	**U-value**
1	(Inside) 20 mm – Plaster 120 mm – Precast concrete 300 mm – Insulation 50 mm – Wooden structure (Air cavity) 10 mm – Ceramic tiles (Outside)	500 mm	362.700,0 dkk	0.091
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price**	**U-value**
2	(Inside) 20 mm – Plaster 100 mm – Lightweight concrete 200 mm – Insulation 100 mm – Precast concrete (Outside)	420 mm	147.337,2 dkk	0.15

PITCHED ROOF				
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price**	**U-value**
1	(Inside) 400 mm – Insulation 20 mm – Timber panels 30 mm – Timber laths (Air cavity) 20 mm – Ceramic tiles (Outside)	470 mm [9]	97.727,5 dkk	0.077
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price**	**U-value**
2	(Inside) 320 mm – Insulation 100 mm – Concrete slab 30 mm – Timber laths (Air cavity) 20 mm – Ceramic tiles (Outside)	470 mm	- [10]	0.09

[8] Approximated prices found in Sigma database

[9] The wood trusses of the structure are not included due to the insulation is placed between them, so they don't increase the thickness of the solution

[10] The Price of this element has not been studied due to the other option is going to be applied because of the better U-value and less weight of the construction.

GROUND FLOOR[11]				
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price**	**U-value**
Contact with soil	(Inside) 20 mm – Cement tiles 120 mm – Concrete + floor heating pipes 350 mm – Insulation 50 mm – Cement screed (Outside)	540 mm	939,5 dkk/m^2	0.08
Option	**Layers (Thickness + Materials)**	**Total thickness**	**Price**	**U-value**
Contact with basement	(Inside) 20 mm – Cement tiles 120 mm – Concrete + floor heating pipes 350 mm – Insulation 20 mm – Gypsum board (Outside)	510 mm	939,5 dkk/m^2	0.097

Options chosen

For the external walls the option number 1 have been chosen. Even it has more thickness and the price is higher, the U-value is much lower than the one for the option 2, and it has more influence when choosing the options.

In the case of the pitched roof, 2 options with different constructive solutions have been considered, though the second one has been discarded due to the extra weight it supposed for the structure. Even if it is not studied, this consideration is important to make the project procedure more realistic.

Regarding the ground floor, it has been decided that the original project have a good energy behavior, so just some thickness have been changed and it has been calculated separately for knowing the U-value, due to the external resistance of the outer layer that changes depending if it is soil or air. This is the example of U- value's calculation for the ground floor in contact with the soil, and the Rsj has been found in DS418.

Table 6.9.1 – Resistance for soil R_j

Component	m^2 K/W
$\boxed{\text{Ground supported floor, from 0.5 m above to 0.5 m below the terrain}}$	$\boxed{1,5}$
Basement floors, deeper than 0.5 m below the terrain	2,0
Basement walls	
Until 2 m below the terrain (h is the depth in m)	0,2 + 0,3h
More than 2 m below the terrain and under the building	2,0

[11] It has been decided that the original proposal of this element is good, so the same materials are kept, but changes on the thickness of them to improve the U-value have been applied

Groundfloor (in contact with soil)						
Layers	**Thickness (m)**	**Conductivity (W/mK)**	**Resistance (m2K/W)**	**U-value (W/m2K)**	**BR08**	**BR10**
Rsi			0,17	0,08	0,15	0,10
Cement tiles	0,02	1,5	0,01			
Concrete	0,12	2,1	0,06			
Insulation	0,35	0,035	10,00			
Cement	0,05	1,4	0,04			
Rsj			1,50			
Total	**0,54**		**11,78**			

The table below shows a summary of the final chosen building envelope elements, with its U-value and thicknesses:

Element	Option chosen	Thickness (mm)	U-value (W/m^{2}K)
External walls	1	500	0.091
Pitched roof	1	470	0.077
Ground floor – Soil	-	540	0.08
Ground floor - Basement	-	510	0.097

Spain

In the case of the Spanish legislation, the U-values calculated before followed the same process and formulas[12], but the limits are different depending on the climatic zone were the house should be placed. For that this will be calculated to know which limits should be taken into account.

Climatic zone

To know the climatic zone where the village is located, it's needed to be known its height above the see level and to check the table B.1 of the Appendix B from DB-HE 1. There, knowing the province to which it pertains and the height of the village, which is 391 m above the see level, it can be seen that the climatic zone is the called C3.

[12] According DA DB-HE / 1 - Cálculo de parámetros característicos de la envolvente (February 2015) the formulas to calculate U-values are the same ones tan the used for the Danish case.

Tabla B.1.- Zonas climáticas de la Península Ibérica

Zonas climáticas Península Ibérica																		
Capital	**Z.C.**	**Altitud**	**A4**	**A3**	**A2**	**A1**	**B4**	**B3**	**B2**	**B1**	**C4**	**C3**	**C2**	**C1**	**D3**	**D2**	**D1**	**E1**
Albacete	D3	677										h < 450			h < 950			h ≥ 950
Alicante/Alacant	B4	7					h < 250					h < 700			h ≥ 700			
Almería	A4	0	h < 100				h < 250	h < 400				h < 800			h ≥ 800			
Ávila	E1	1054														h < 550	h < 850	h ≥ 850
Badajoz	C4	168									h < 400	h < 450			h ≥ 450			
Barcelona	C2	1											h < 250			h < 450	h < 750	h ≥ 750
Bilbao/Bilbo	C1	214												h < 250			h ≥ 250	
Burgos	E1	861															h < 600	h ≥ 600
Cáceres	C4	385									h < 600				h < 1050			h ≥ 1050
Cádiz	A3	0		h < 150				h < 450				h < 600	h < 850			h ≥ 850		
Castellón/Castelló	B3	18						h < 50				h < 500			h < 600	h < 1000		h ≥ 1000

U-values

In the next table, found in section 2 of DB-HE 1, it can be found the maximum values for the transmittances or U-values, so it is possible to compare them with the obtained before and then see if the improvements fulfills the Spanish regulations.

Tabla 2.3 Transmitancia térmica máxima y permeabilidad al aire de los elementos de la envolvente térmica

Parámetro	Zona climática de invierno					
	α	**A**	**B**	**C**	**D**	**E**
Transmitancia térmica de muros y elementos en contacto con el terreno(1) [W/m²·K]	1,35	1,25	1,00	0,75	0,60	0,55
Transmitancia térmica de cubiertas y suelos en contacto con el aire [W/m²·K]	1,20	0,80	0,65	0,50	0,40	0,35
Transmitancia térmica de huecos(2) [W/m²·K]	5,70	5,70	4,20	3,10	2,70	2,50
Permeabilidad al aire de huecos(3) [m³/h·m²]	≤ 50	≤ 50	≤ 50	≤ 27	≤ 27	≤ 27

Comparison of U-values

Now it is possible to compare the U-values obtained from the improved project with the required ones by the legislation, to see if they are fulfilled or if there is a need to change the solutions implemented.

Parameter	Improved U-value	CTE U-value
External walls	0.091	0.75
Pitched roof	0.077	0.5
Ground floor	0.08	0.5

As can be seen in this comparative table, the U-values required by the Spanish legislation are higher than the ones obtained. In a case like that, the ones obtained with the new solutions studied will be kept, so any other changes will be done in the house.

Windows and doors

The glazed elements are also the ones through whom a big amount of heat is lost. By choosing a better pane and a frame with a better performance, it's possible to reduce considerably the U-value and, consequently, increase the insulating properties of the whole building envelope.

Denmark

The original windows and doors had its U- value inside the required limits of the legislation: they had a U-value of 1.4 W/m^2K and the maximum stated in BR10 is 1.8 W/m^2K. Nevertheless is always good to improve this parameters, and in this case, to assure a good improvement of this value, the new pane and frame have been selected from the Passive House Institute database of certified manufacturers. It has been made in this way because the Passive House Institute requires a U-value for windows of 0.85 W/m^2K, much lower than BR10 requirements.

New types of windows

As will be explained later on in the study of Indoor environment- Daylight factor, the windows have been changed in order to increase it, so the Calculations of U-values will be according this new types of windows. Specifically, two new windows have been considered, called W8 and W9 and the data of them is shown below:

Window type	Units	Width	Height	Area
W8	1	2.5	1.2	3
W9	2	1.5	1.2	1.8

Manufacturer and materials[13]

From the Passive House database have been chosen a type of pane and a type of frame. These elements have different values that will be needed later for the calculation of the U-value, and also to input into a new simulation with BE10.The data that will allow the calculation of the total U-value is the individual U-values for both pane and frame and the linear loss of each of them. Another important value, this time to insert it in BE10 is the g-value of the glass.

Glass

The glass chosen is from AGC Glass Europe s.a. manufacturer, product iPlus Advanced 1.0. The model is a 3-layer energy glass, which U-value is 0.44 W/m^2K, and its g-value is 0.42.

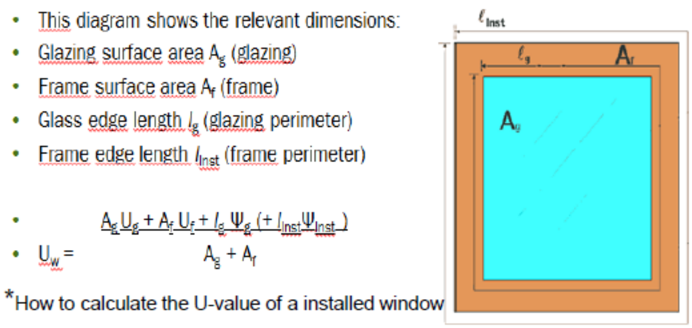
[13] The technical data for both glass and frame can be found in Annex B.2

Frame

The manufacturer of the frame is ZAo BiTri, and the product is called RUKNA-1. This frame has a U-value of 0.6, is made with aluminum and its width is 0.11 m.

U-values

The U-value of the windows is calculated in a different way than the used for the other building components. In this case, it has been taken the formula and values of linear loss from teacher slides of the subject PAH-CS1.



The data that is going to be used is the U-values shown before, areas, perimeters and linear losses. The following tables shows the data taken for this calculation and the final U-values obtained.

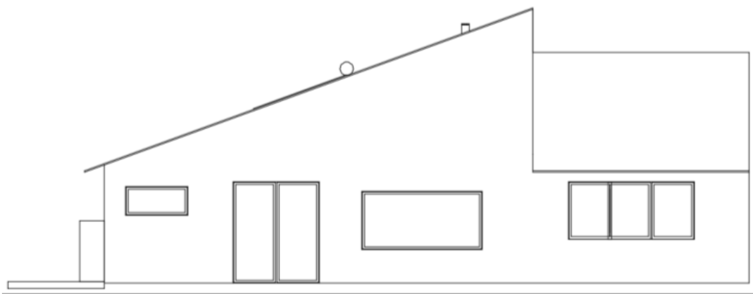
Element	U-value	Linear loss
Glass	0.44	0.03
Frame	0.6	0.02

As it is possible to check in the summary table below, the U-values obtained are much lower than the requirements of BR10, so is possible to expect, with this values and the ones from the building envelope, a big reduction of the Design transmission loss for building envelope and Energy performance framework. Later on, it is possible to see where the new windows are placed in the building envelope.

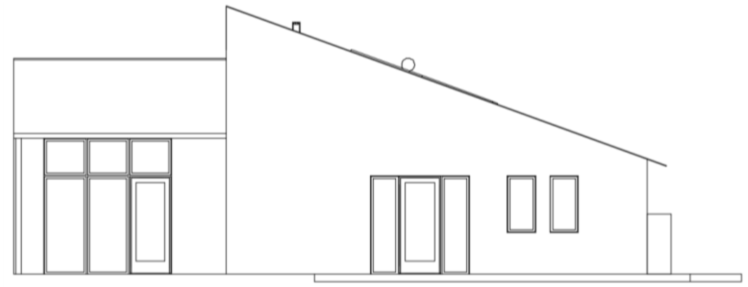
Summary table

Element	Glass Area (m²)	Glass Perimeter (m)	Frame Area (m²)	Frame Perimeter (m)	Window Area (m²)	U-value (W/m² K)
D	1.71	5.76	0.18	6	1.89	**0.61**
W1	1.83	5.92	0.06	6	1.89	**0.6**
W2	0.69	3.32	0.034	3.4	0.72	**0.68**
W3	0.96	3.96	0.126	4.2	1.08	**0.65**
W4[14]	-	-	-	-	-	**-**
W5	0.62	3.36	0.108	3.6	0.72	**0.71**
W6	1.21	5.32	0.054	5.4	1.26	**0.66**
W7	0.67	3.56	0.114	3.8	0.78	**0.7**
W8	2.93	7.32	0.074	7.4	3	**0.57**
W9	1.75	5.32	0.054	5.4	1.8	**0.59**

Location in the building envelope

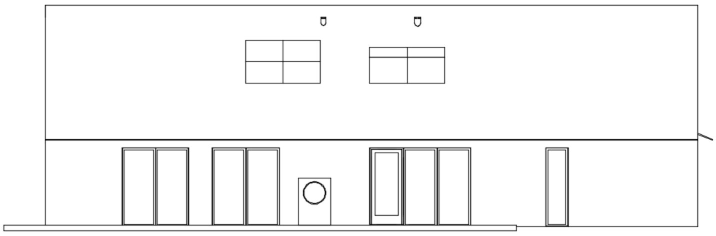


Elevation North. From left to right: W7, 2 x W1, W8, 3 x W3

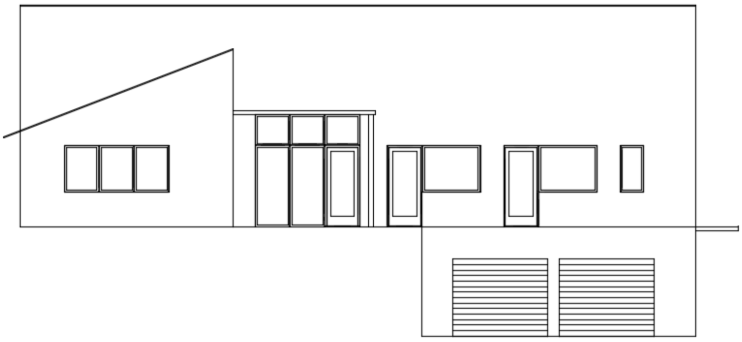


Elevation South. From left to right, above: 3 x W2
From left to right, below: 2 x W1, D, W6, D, W6, 2 x W5

[14] Due to the study of Daylight Factor and the changes made on the Windows, the type W4 is not installed in this new proposal.



Elevation East. From left to right: 4 x W1, D, 2 x W1, W6



Elevation West. Above: 3 x W2
From left to right: 3 x W3, 2 x W1, 2 x D, W9, D, W9, W5

Areas

For the BE10, the areas of both Windows and Building envelope elements should be input. The areas for each type of window have been calculated above, but the ones for the building envelope have changed. This is due to the new layout of windows to increase the daylight factor (the area of the openings needs to be deducted from the area of the element) but also because the building envelope limits have changed from the original project to this new proposal. For example, the external walls are now pertaining entirely to the building envelope (before, they were building envelope just until the flat roof). A summary table is useful to have a clear idea of all the areas to input in BE10.

Nº	Name of element	Area (m^2)
1	North façade-Big	26.9
2	North façade-Small	7.11
3	South façade-Big	28.65
4	South façade-Small	12.65
5	East façade	25.5
6	West façade-Big	65.23
7	West façade-Small	14.56
8	Roof	201.5
9	Ground floor-Soil	176.27
10	Ground floor-Basement	66.24

Spain

In this case even the U-value of the original project (1.4 W/m^2K) was much lower than the required one by the Spanish legislation. However, in order to improve the global energy behavior of the building, the changes implemented with its new U-values will be taken, so at the end the parameters will remain like it's shown in this summary table of U-values.

Tabla 2.3 Transmitancia térmica máxima y permeabilidad al aire de los elementos de la envolvente térmica

Parámetro	**Zona climática de invierno**					
	α	**A**	**B**	**C**	**D**	**E**
Transmitancia térmica de muros y elementos en contacto con el terreno(1) [$W/m^2 \cdot K$]	1,35	1,25	1,00	0,75	0,60	0,55
Transmitancia térmica de cubiertas y suelos en contacto con el aire [$W/m^2 \cdot K$]	1,20	0,80	0,65	0,50	0,40	0,35
Transmitancia térmica de huecos(2) [$W/m^2 \cdot K$]	5,70	5,70	4,20	3,10	2,70	2,50
Permeabilidad al aire de huecos(3) [$m^3/h \cdot m^2$]	≤ 50	≤ 50	≤ 50	≤ 27	≤ 27	≤ 27

Parameter	**Improved U-value**	**CTE U-value**
Windows and glazed doors	0.57-0.7	3.10

Installations

From the results obtained in the simulation program BE10 for the original project was deduced that including installations for renewable energies could be a good solution to improve the energy consumption of the house. But other reason, as is the case of including a ventilation system, is the improvement of the indoor environment, specifically the atmospheric indoor climate. With a good ventilation system, there is not only ensured the minimum airflow of fresh and clean air supply, but also the humidity and the control of CO_2 and other pollutants levels.

Ventilation system

Denmark

The original ventilation system consisted only in extraction in kitchen and bathrooms, so it was considered natural ventilation. This time, the system studied will be mechanical ventilation, including the extraction in kitchen, bathrooms and laundry room, but also supply in every living space.

To develop a good ventilation system, some steps should be followed, starting from the minimum airflows for both supply and extract, propose a pathway for the distribution of the air, dimensioning the ducts depending on the airflow and the velocity of the air as well as the diffusers in each room, and at last but not least, the selection of a suitable ventilation unit.

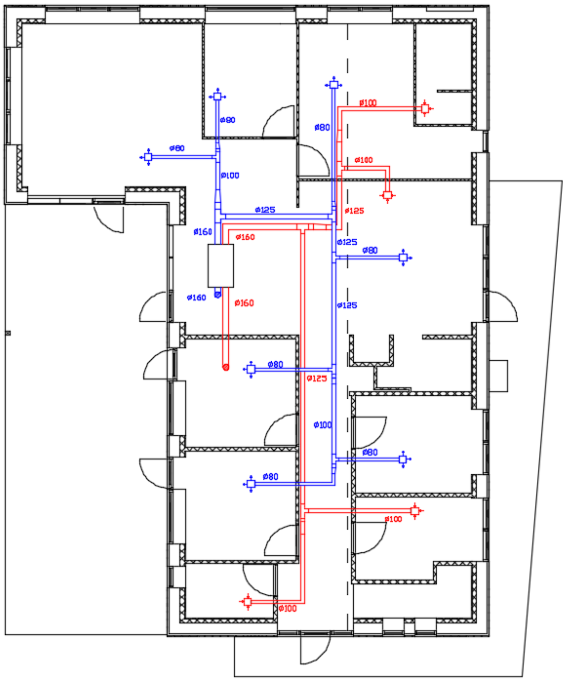
Airflows

The airflows for the house are going to be the same ones than the studied for the ventilation of the original project. Assuming the values described in point 6.3 of BR10, that are 20 l/s of extract air for kitchen, 15 l/s for each bathroom and 10 l/s for the laundry room, a final airflow of 60 l/s is obtained. That means that the supply air airflow should be of 0.40 l/s/m^2 in order to create a balanced ventilation. The following summary table shows the final airflows in different units, which are going to be useful later on to dimension the ducts and to choose the ventilation unit.

	l/s	m3/s	m3/h
Extraction	60	0,06	216
Supply	60	0,06	216

Pathways

It's important to choose the location of the ducts in order to know which kind of duct will be (if main duct, branch or connection duct) and also which airflow will go through each of them. Due to the location of the ventilation unit will be the insulated attic, the ducts can go also around this attic, and there is no need to add an extra suspended ceiling to distribute them. But an important point to take into account is the height of the roof. The roof has a 20º inclination, and due to it's a new part of the building envelope and has been insulated, its thickness has increased to the inside, so the attic has less space to locate the ducts. Will be necessary to check this height for the case of the kitchen and the main bathroom, the two spaces that are closer to the lower point of this ceiling.



This plan shows the pathway layout. The legislation requires to have extraction diffusers in every extraction zone, but also supply diffusers in the other living spaces of the house. This restrictions mean that the house will have a total of 4 extraction diffusers and 7 supply diffusers, as can be seen in the picture.

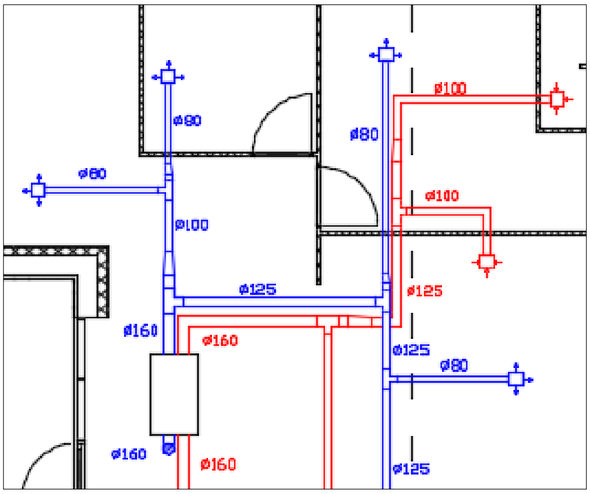
The dashed line crossing the building shows the joint between the highest ceiling and the insulation of the pitched roof. In the building there are two heights for the ceiling: The highest one comprehends all the common area until a height of 3.2 m and the lower one, with a height of 2.4 is placed on the other rooms.

Is for this reason that the branch duct that connects the ventilation unit with the main bathroom and the kitchen should go in parallel to the joint between the highest ceiling and the pitched roof, until it arrives to the lower ceiling, where can connect to the extraction diffusers without more problems.[15]

Another important point to take into account is where are going to be placed the ducts to take the fresh air from the outside air and the extraction duct. They should be a bit separate between each other to not create an influence of airflows (for example, the supply diffuser could take some of the polluted extracted air from the building). A former proposal placed this diffuser into the west façade to the terrace, but the aesthetics of this solution wasn't appropriate, so finally they have been placed in the roof.

[15] This changes on the height can be seen in Annex C, Drawings.

Dimension of ducts



The dimension of ducts depends on which type of duct is each one, the velocity of the air is flowing through them and the airflow. The total airflows have been calculated before, and knowing now the number of diffusers, it is possible to know the airflow per diffuser that should be supplied or extracted. The values are 15 l/s/diffuser for extract air and 9 l/s/diffuser for supply air.

A type for each conduct should be defined, being main duct the one that goes from/to the ventilation unit, branch duct the one that distribute the air, and connection duct the one that connects the diffusers to the branch duct. This is important to know because depending on which type of duct, the air velocity through it changes.

With this data, and the air velocity and dimensioning formula both extracted from *Ventilation and Indoor Climate*[16] , it's possible to dimension all the ducts. The table below shows this calculation, and the pictures are the data extracted from Ventilation and Indoor Climate.

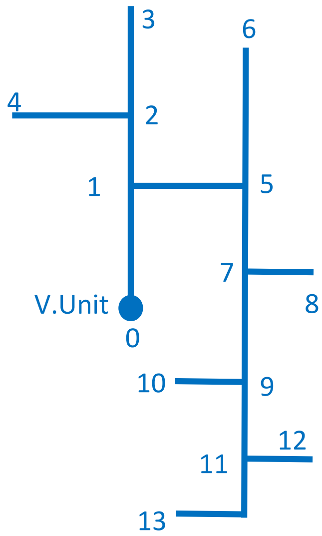
$$d = \sqrt{\frac{q \cdot 4}{v \cdot \pi}}$$

q = Air amount (m^3/s)

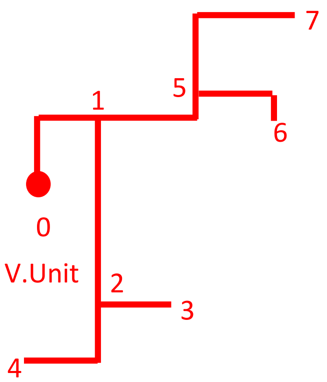
v = Air velocity (m/s)

	Recommended air velocity in m/s		
	Dwellings	Schools Offices Theatre Etc.	Industrial buildings
Main duct	3,5 – 4,5	5,0 - 6,5	6,0 – 9,0
Branch duct	3,0	3,0 – 4,5	4,0 – 5,0
Connection duct	2,5	3,0 – 3,5	4,0

[16] Ventilation and Indoor Climate. Jens Peder Pedersen. VIA University College.



Supply						
Conduct	Type of conduct	Airflow (m3/s)	Velocity (m/s)	Duct dimension (m)	Duct dimension (mm)	Standard dimensions (mm)[17]
0-1	M	0.06	4	0.142	142	160
1-2	B	0.018	3	0.087	87	100
2-3	C	0.009	2.5	0.068	68	80
2-4	C	0.009	2.5	0.068	68	80
1-5	M	0.045	4	0.120	120	125
5-6	C	0.009	2.5	0.068	68	80
5-7	B	0.036	3	0.124	124	125
7-8	C	0.009	2.5	0.068	68	80
7-9	B	0.027	3	0.107	107	125
9-10	C	0.009	2.5	0.068	68	80
9-11	B	0.018	3	0.087	87	100
11-12	C	0.009	2.5	0.068	68	80
11-13	C	0.009	2.5	0.068	68	80



Extraction						
Conduct	Type of conduct	Airflow (m3/s)	Velocity (m/s)	Duct dimension (m)	Duct dimension (mm)	Standard dimensions (mm)
0-1	M	0.06	4	0.138	138	160
1-2	B	0.03	3	0.113	113	125
2-3	C	0.015	2.5	0.087	87	100
2-4	C	0.015	2.5	0.087	87	100
1-5	B	0.03	3	0.113	113	125
5-6	C	0.015	2.5	0.087	87	100
5-7	C	0.015	2.5	0.087	87	100

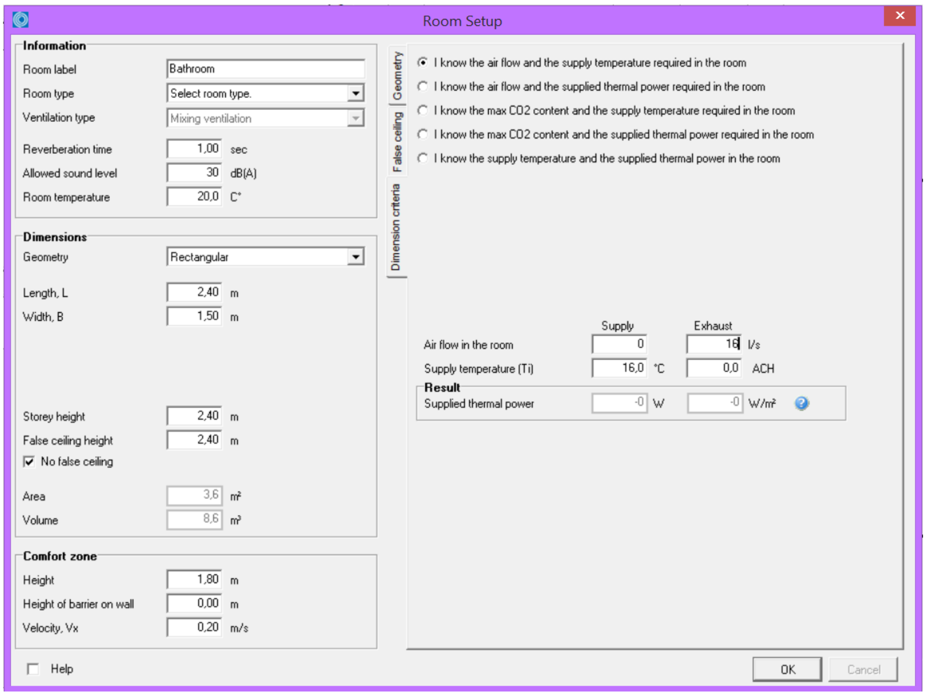
[17] The dimensions calculated in this tables can be seen in Annex C. Drawings with more detail.

Dimension of diffusers

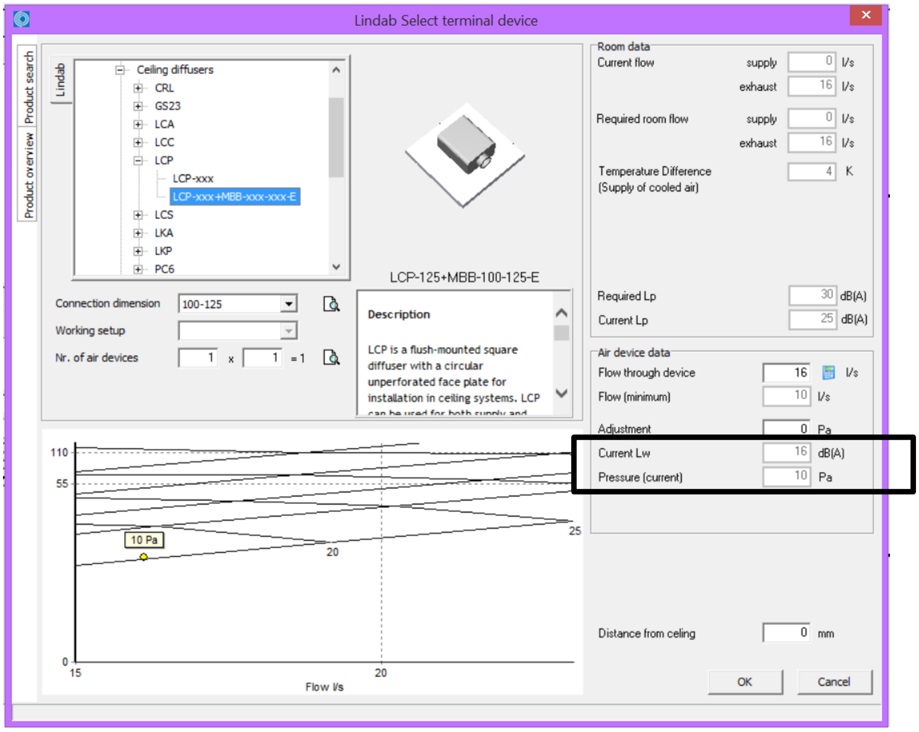
By using the program DIMcomfort it is possible to describe the geometry of the room and select the proper diffuser for this ventilated zone.

From information obtained from teacher slides of the subject Ventilation systems VEN-CS1, It's known that some parameters should be taken into account when dimensioning diffusers, like pressure through them and the sound level.

The range for pressure is between 8-9 Pa minimum, and a maximum of 30 Pa, while for sound level there is only a maximum level that cannot be exceeded of 30 dB. With this values in mind, the information can be input in the program like is shown in the picture.



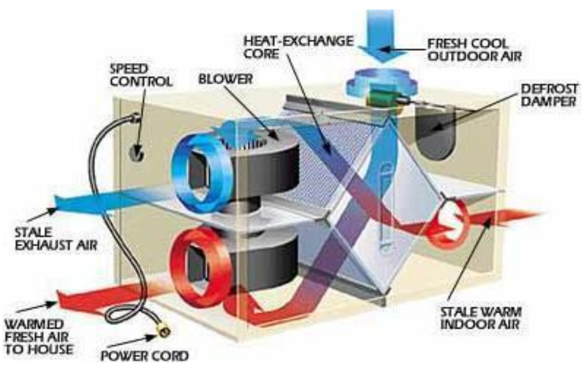
Data regarding geometry of the room is input, as well as the indoor temperature and the calculated airflow. In this case only extraction due to it is described a bathroom. When the room is dimensioned, an exhaust diffuser is inserted and another menu to choose it appears. In this menu, the size can be selected and also the number, in case of bigger rooms. Even can be selected manually both the size and number, the program can also calculate which values are more appropriate for the described room. In the right part of the picture can be checked the pressure and sound level that the diffuser has.



After analyzing every room of the house, it can be seen that every diffuser has the same size, *100x125 mm*, and all of them have an average of *9 Pa* of pressure and around *15 dB*, so can be conclude that every diffuser fulfills all the requirements.

Ventilation unit

The ventilation unit is chosen depending on the total airflow that it should move, but in this case of a low energy consumption house, it is important to choose a ventilation unit with heat recovery. This is important because in that way, the air heated inside and extracted transfers this heat to the air is going inside, so much less energy is needed to heat up this fresh air supply. This pictures shows the principle of the heat recovery.



Due to the total airflows have been calculated before, is known that the ventilation unit should be able to move a total air amount of 216 m^3/h. From the BR10 is also known that the efficiency of the ventilation units should be up to a 75% at least, so using this data is possible to look for a good ventilation unit from the manufacturer webpage. In this case, Exhausto manufacturer has been selected, finding the model VEX330H, which fulfills all the requirements needed.[18]

[18] Technical information of this Ventilation unit can be found in Annex B.3. Installations

Spain

In order to dimension the ventilation system following Spanish regulations, it should be taken into account Reglamento de instalaciones térmicas en los edificios (RITE) version from 2013.

According to the table 1.4.2.1 from this document, in order to know the airflow needed in the installation, the quality of the air inside the building is needed before. The chosen option has been the named IDA 2, which means this air has a good quality. Now, it is possible to extract from the table the airflow needed.

Tabla 1.4.2.1 Caudales de aire exterior, en dm^3/s por persona	
Categoría	dm^3/s por persona
IDA 1	20
IDA 2	12,5
IDA 3	8
IDA 4	5

Now it is possible to calculate the total airflow will go through the installation. Due to 1 dm^3 is equal to 1 liter, the requirement means that the minimum airflow should be 12.5 l/s per person. As the building will be used by a family of 4 members, the airflow obtained is:

12.5 (l/s/p) **x** 4 (p) **= 50 l/s**

With this value now is possible to know if the dimensioning of the installations according Danish Building regulations is enough to fulfill the Spanish requirements. As can be seen in the comparative table below, the installation has been dimensioned according an airflow of 60 l/s, higher than the required one by the CTE, so can be conclude that the ventilation system will work properly with this values.

	DK airflow	**ES airflow**
Minimum airflow (l/s)	60	50

Heat pump

Denmark

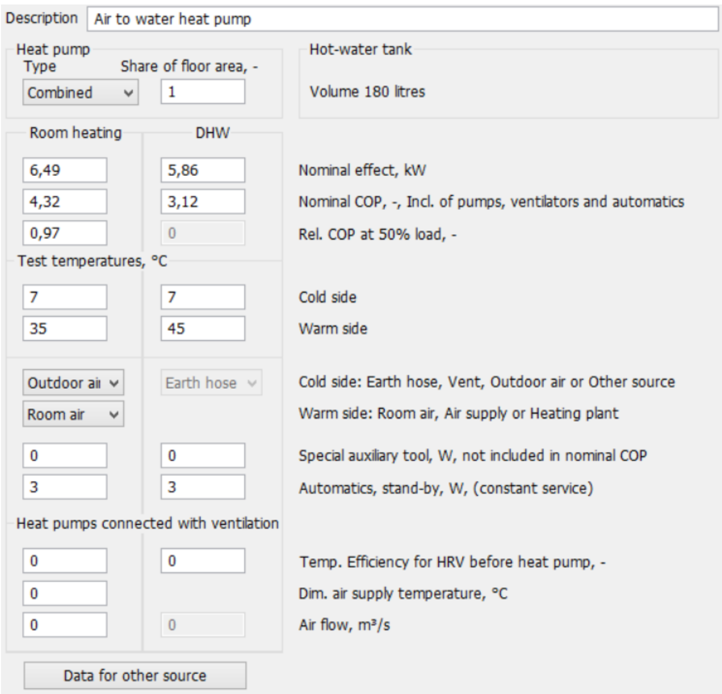
The original project defined the installations as connected to the district heating, but for this one, a heat pump has been installed. In this way it is possible to be disconnected from the grid of district heating and be self-sufficient. Also, connected to the district heating there are heat losses through the supply pipes, while this length is decreased by installing a heat pump.

The chosen heat pump is an air to water system. This means that the heat pump take energy from the outside air and by compressing it extracts heat, which is transferred to the water loop inside the heat pump. This heated water goes in a closed system inside the water tank and heat up the water inside it, which will be used for the floor heating and for the DHW.

The data needed to dimension it is, first of all, the heat loss of the building. Once all the information regarding the building envelope has been inserted, BE10 will give a value for this heat loss.

The heat pump has been selected from Thermia manufacturer who also has the values of each of its heat pumps adapted to be inserted to BE10. The heat loss obtained from BE10 is 3.3 kW, but there is not such a small heat pump, so the smaller one of 6.49 kW has been chosen.

The picture shows all the data of the heat pump inserted in BE10 corresponding table, and all this information has been found in the manufacturer's guidelines.[19]



[19] The guidelines and technical data of the heat pump can be found in Annex B.3. Installations

Spain

In this case, the solution of a heat pump won't be implemented due to 2 main reasons the source of energy it uses to work. This energy is electricity, and the reasons are:

On the one hand, the price of the electricity in the country. The price here is rather high if it's taken into account that there is a possibility of using renewable energies to warm up the water, and in the other hand, the way this energy has been produced. While in Denmark almost the whole amount of electricity has been produced using renewable energies as are photovoltaic panels or wind mills' farms, in Spain this is not implemented yet, so this electricity come from non-renewable sources.

Thermal Solar collectors

Denmark

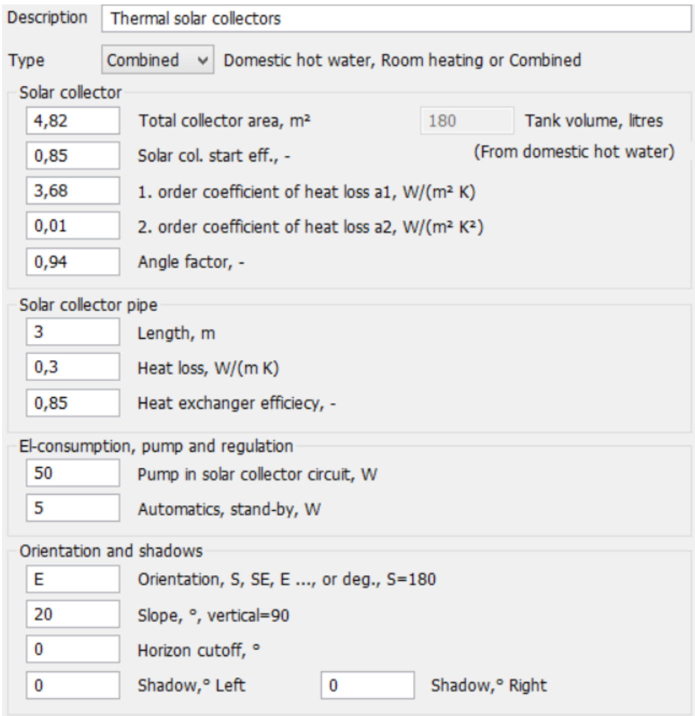
Another renewable energy source installed have been thermal solar collectors. This collectors will take the heat from the sun and warm up the water enclosed in a loop closed system. This closed system goes inside the water tank and warm up the water, and when this heat have been transferred and the water is not warm anymore, it goes back to the collectors that heat it up again.

This system is working together with the heat pump due to both are heating up the same water tank, so smaller surface of Thermal solar collectors is enough to have the same result.

From the technical data of the TS collector is known that one collector has a surface of 2.41 m^2, an efficiency of 85%, and different order coefficients of heat loss. Other information like inclination or orientation of the collectors should be input in BE10, depending where are they placed.

In the table of BE10 it has been input the corresponding data, like the area of 2 thermal solar collectors or the other technical explained above.[20]

[20] Technical data of the Thermal solar collectors is included in Annex B.3. Installations



Spain

While in Denmark this option has been installed as a support energy source for the heat pump, here will be installed in order to supply the whole amount of energy needed to warm up the hot water tank.

First of all, and following the process described in DB-HE 4, it is necessary to know the demand of domestic hot water (DHW) at a temperature of 60ºC. For that is needed the number of persons, this time found in the table 4.2 as can be seen in the picture.

Tabla 4.2. Valores mínimos de ocupación de cálculo en uso residencial privado

Número de dormitorios	**1**	**2**	**3**	**4**	**5**	**6**	**≥6**
Número de Personas	1,5	3	4	5	6	6	7

Having the number of persons it is possible to know the demand from the following table.

Tabla 4.1. Demanda de referencia a 60 °C[1]

Criterio de demanda	Litros/día·unidad	unidad
Vivienda	28	Por persona

With both values it is possible to calculate the total demand of DHW needed, obtaining a value of 28 (l/d/p) x 5 (p) = **140 l/d**

From the simulations made for the Danish case, it is known that the hot water tank selected is one of 180l, so the total demand needed is fulfilled.

The legislation also asks about the minimal solar contribution per year, depending the climatic zone where the village is placed. This climatic zone refers to the solar radiation, so it's different from the previous climatic zone C3. To be able to know the climatic zone it's necessary the H value, or mean value of solar radiation, which should be extracted from *Atlas de Radiación solar en España utilizando datos del SAF de Clima de EUMETSAT.*

From this document of 2012 can be extracted the mean value H for the capital of province where Vilafamés belongs, and applying this value H to the table 4.4 it's possible to know the climatic zone. The H value obtained is **4.76 kWh/m²/d**, so the climatic zone is the IV.

Tabla 4.4. *Radiación solar global media diaria anual*

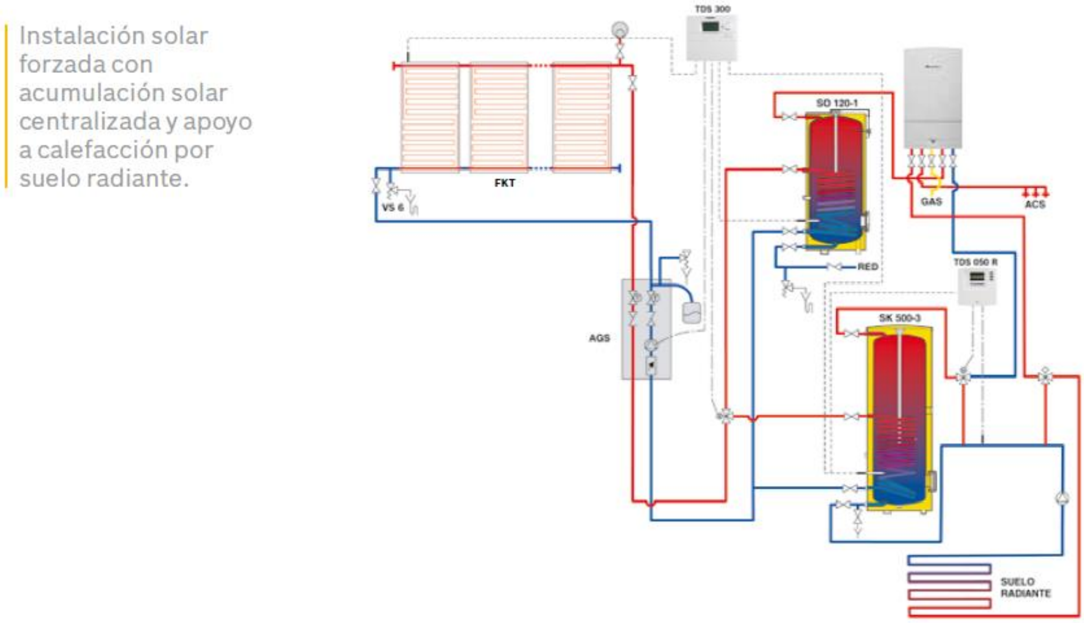
Zona climática	MJ/m²	kWh/m²
I	H < 13,7	H < 3,8
II	13,7 ≤ H < 15,1	3,8 ≤ H < 4,2
III	15,1 ≤ H < 16,6	4,2 ≤ H < 4,6
IV	16,6 ≤ H < 18,0	4,6 ≤ H < 5,0
V	H ≥ 18,0	H ≥ 5,0

With this climatic zone, the minimal solar contribution per year can be seen in the table 2.1

Tabla 2.1. Contribución solar mínima anual para ACS en %.

Demanda total de ACS del edificio (l/d)	Zona climática				
	I	II	III	IV	V
50 – 5.000	30	30	40	50	60
5.000 – 10.000	30	40	50	60	70
> 10.000	30	50	60	70	70

After obtaining all this data, it's time to dimension the installation of thermal solar panels to supply the demand. The Thermal solar panels chosen are the same ones than the Danish case, and the brand offers advices and guidance about the system to install. This picture extracted from the technical information summarize the system selected for DHW and floor heating:



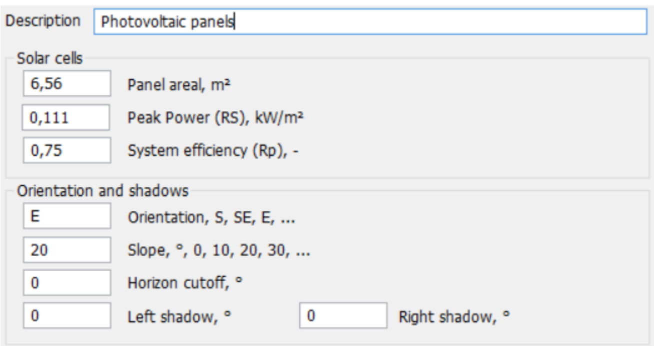
For the model FKT1 can be seen in the technical data of the brand that has an area of 2.25 m^2 and a flow of 50 l/h. This flow means that to heat up the water tank of 200l in 1h will be need to be installed a total of **4 thermal solar panels**, which means a total area of 9 m^2.

This system is connected to a gas natural boiler, so in case that due to bad weather or other reasons the thermal solar panels won't be enough to supply the total need of heat and DHW, this boiler will supply the needed demand.

Photovoltaic panels

Denmark

Solar cells have been considered in order to supply some of the electricity needed by, for example, the ventilation unit or the heat pump. Batteries are installed in order to store the energy generated, and from there is taken to the devices that needs it. It can be supplied to any electrical device of the house, but in this case, the installation has been thought for the other installations like the heat pump or the ventilation, to reduce the amount of energy taken from the grid.



The BE10 simulator ask about the area of the panels, 4 solar cells in this case, and the peak power or efficiency.[21] Also about the information regarding the orientation and angle once they are installed.

Both solar cells and thermal solar collectors are placed in the pitched roof facing east, and this information is shown in Annex C. Drawings.

Spain

As has been explained in a former point, in the Danish case there is no need of using other source than electricity, due to there this energy is made in a renewable way. However this is not the case in Spain so it's important to try to apply PV panels in order to supply the total demand of the house.

Because of recent changes in the legislation, is not possible to install a PV panels' installation if it's not able to supply the total amount of energy needed. For example, it's not allowed to have PV panels and be connected to the grid at the same time. For this reason, if the installation requires a higher area than the available one or the price of it is too high, will be considered to be connected to the grid.

According to DB-HE 5, should be known the minimal nominal Power with the formula 2.1, applying a climatic coefficient and the gross area of the building. The climatic coefficient is found in the table extracted from the same section of CTE.

Tabla 2.1 Coeficiente climático

Zona climática	C
I	1
II	1,1
III	1,2
IV	1,3
V	1,4

$$P = C \times (0.002 \times S - 5)$$

$$P = 1.3 \times (0.002 \times 270 - 5)$$

$$\mathbf{P = 0.689\ kW = 689\ W}$$

From the legislation can be extracted also the production ratios depending on the climatic zone, so it can be conclude that the production ratio for the climatic zone IV is of 1.632 kWh/kW

Tabla 2.2 Ratios de producción por zona climática

	Zona I	Zona II	Zona III	Zona IV	Zona V
Horas equivalentes de referencia anuales (kWh/kW)	1.232	1.362	1.492	1.632	1.753

[21] Technical data of the Photovoltaic panels is included in Annex B.3. Installations

To dimension the installation, the tool PVGIS (*Photovoltaic Geographical Information Systems – Interactive maps*) is used, and adding the data of the house can be extracted the information of the installation.

The data needed, first of all, is the location of the house, and also the type of PV panel installed (crystalline silicon). But it's not possible to know the peak power of the installation if it's not known the amount of PV panels to install, and in order to decide this number, it's necessary to know which will be the total consumption of electricity of the house.

Due to the electrical installation of the house has not been dimensioned, is not possible to know an exact number of what will be the consumption. For this reason, an approximated number will be considered, and to have a realistic consumption, some information has been looked for in 2 different sources: Iberdrola and OCU.org. In this sources there are examples of mean values of electrical consumptions in detached single family houses, and they are 9725 kWh/y and 9922 kWh/y, respectively. From this values it can be extracted a mean value from both of them in order to have an approximated consumption, which is **9823.5 kWh/y**.

Another important point to take into account is the slope and orientation of the roof. There are two roofs with two different orientations: the big one to the southwest and the smaller one to the southeast. In this case, the best orientation is the smaller one, and it has a slope of 21º.

Also the number of panels should be decided in order to have information about the total peak power of the installation. To know more or less the number of panels it's possible to try different solutions with the program: this time, it has been considered as the whole small roof has been covered with them, so knowing the areas of the roof and the panels it's possible to know that 12 panels can fit there, with a resultant 3 kWp as peak power.

When all this data is input in the digital tool, the program calculates the annual power production of the installation. With this number of panels can be reached a power of 3880 kWh. This power is much lower than the expected consumption stated before, 9823.5 kWh, so with 12 panels won't be enough to cover the whole demand.

To know the exact amount of panels, by knowing that there is a need of achieving 5943.5 kWh more than the obtained power, can be deduced that more than the same amount of panels should be installed in the other roof. In fact, if it's considered that again 12 panels are installed in the other roof, the amount of electricity produce will be of 3740 kWh, so can be seen that should be almost the double of the panels what should be installed in the big roof to achieve the needed electricity.

At this point, a decision should be made considering if it's worthy to implement a PV panels installation or not, because there will be a need of install more than 36 panels, so this will have a huge economic impact to the client. If it's considered that each panel has a price of more or less 200€, without counting here installation of it and other products as batteries, just the panels will cost 7200€.

If the digital tool of Iberdrola for calculating an average of consumption is used again, it can be seen that the price of this electricity each year is of 1824 €/y, so the installation of the panels will be amortized in almost 7 years.

Consumo anual:	9775 kilowatios/hora por año
Coste anual:	1824 euros por año
Coste mensual medio:	152 euros por mes

Because of all the information analyzed, and taking into account that the cost of other products for the installation haven't been considered, it has been decided that the PV panels installation is not worthy to be installed if it needs to cover the total consumption, as has been stated in recent legislations about PV panels.

Other renewable energies

Denmark

It was also considered the option of installing geothermal energy and wind mills in the plot, but this options have been discarded.

In the case of wind mills, the system is very expensive to be affordable for a single family, and there can also be problems related with the noise made by the blades and the turbine.

The geothermal system could have been constructed in two different ways: a superficial loop or a borehole. The borehole would have been much more efficient than the superficial loop, but both of them are very expensive, due to its construction involved in both cases excavations, large length of pipes and a water to water heat pump.

Spain

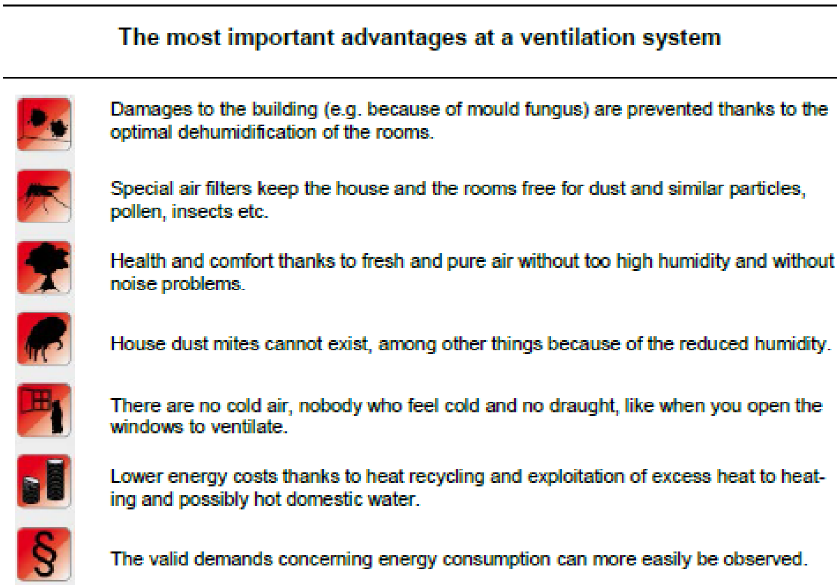
In this case the same consideration of the Danish case have been taken into account. It's not possible to install a wind mill for a single family house, and about the geothermal energy, is not necessary due to the Thermal solar panels installation can cover the whole need of Domestic Hot Water and heating demand.

Indoor environment

Atmospheric indoor climate

Denmark and Spain

The same conditions than the ones explained in the original project analysis should be fulfilled, but this time, it has been improved by the implement of a mechanical ventilation system, that ensures a good indoor quality with regulation of humidity, CO_2 and other pollutants levels. The importance of the ventilation system can be seen in this summary extracted from *Ventilation and Indoor Climate.*


The most important advantages at a ventilation system

- Damages to the building (e.g. because of mould fungus) are prevented thanks to the optimal dehumidification of the rooms.
- Special air filters keep the house and the rooms free for dust and similar particles, pollen, insects etc.
- Health and comfort thanks to fresh and pure air without too high humidity and without noise problems.
- House dust mites cannot exist, among other things because of the reduced humidity.
- There are no cold air, nobody who feel cold and no draught, like when you open the windows to ventilate.
- Lower energy costs thanks to heat recycling and exploitation of excess heat to heating and possibly hot domestic water.
- The valid demands concerning energy consumption can more easily be observed.

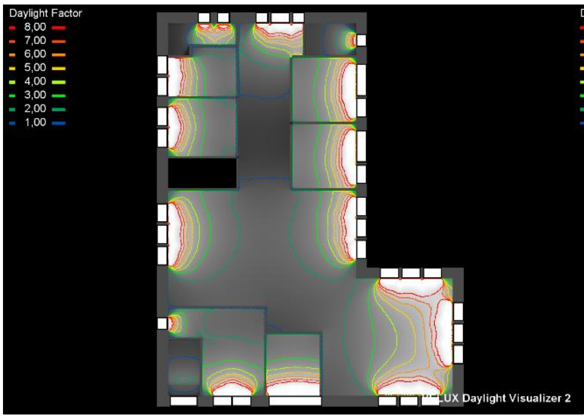
Visual indoor climate

Denmark

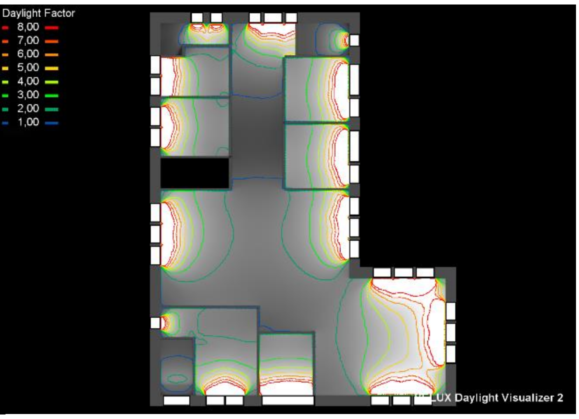
As it has been analyzed for the original project, the Daylight factor were not enough in some of the rooms, so new types of windows have been installed.[22] When the types of windows have been decided, the simulation with VELUX daylight visualizer has been done again, to check if the solution implemented is good enough. Now, the minimum of 2% for a cloudy day in January is reached in a higher area of the building, and in the bedrooms and office is reached where the desk will be placed. After this changes, the thermal indoor climate should be studied again, because an increase of the glazed area can become in an increase of the overheating.

Spain

In Spanish legislation there is no limits about the daylight. Also can be expected better results due to the country's location: the more to the south the country is placed, the higher amount of sunlight it will have. However, a simulation has been done again to show the new location and orientation, and three different moments during the year can be seen in the next pictures.

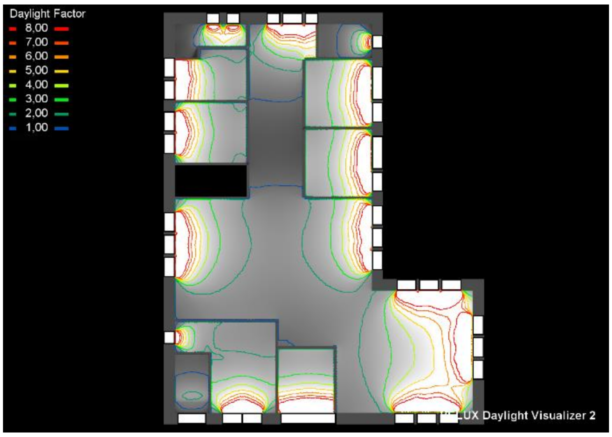


January



March

[22] Information about the sizes, types and location in the building envelope of this windows can be found in the point Windows and doors inside the analysis of the new proposal.



July

The program assumes that any kind of object is placed to give shadows to the windows, for that can be seen the huge difference between the two countries, differences because of the location of the country and the orientation of the house. While in the Danish case was difficult to get the minimum Daylight Factor of 2%, in this case there is even too much light, arriving until an 8%, so there will be a need of installing blinders and curtains in almost every window of the house.

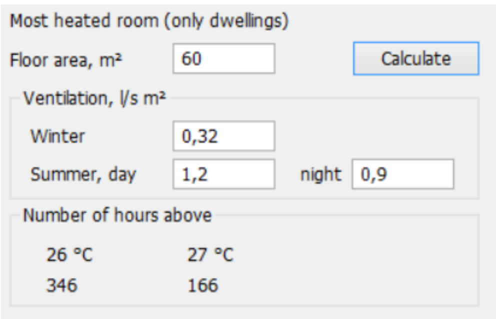
Thermal indoor climate

Denmark

As explained in the original project analysis, the optimal indoor temperature is assumed as 20ºC, and this can be achieved with good heating and ventilation systems. However, there are some heat gains through the windows, and the heat remains inside the building do to the tightness of the building envelope. That can become in an increase of this temperatures to uncomfortable limits, delimited by 26º and 27ºC. For this reason BR10 delimitates the amount of time during a year this temperatures can be achieved. As explained in other points, no more than 100h per year at 26ºC and no more than 25h per year at 27ºC.

In the original project there where a large amount of time over this limits, and now, with the new windows installed to achieve the Daylight factor minimum value, this numbers will have been increased for sure.

The data of the new building envelope have been inserted in BE10, as well as the new windows and the shadings, which remains the same ones than the analyzed for the original project. After inserted the data, the windows pertaining to the common space have been selected to know the amount of overheating, obtaining the following values.



It can be seen that, even the time of overheating have decreased due to the ventilation system implementation, the values are not inside the limits yet. Other solutions should be applied, and more shadings are going to be considered.

The horizontal shadings are the same ones than the existing ones in the original project, and the same happens with the window opening for each window (just values of window openings for W8 and W9 should be added: 2 and 3.3 respectively).

It has been decided to increase the length of the pitched roof to create an eave in the north and east façade, which is the direction of the slope and it casts shadows to some of the windows pertaining to the common area that shown the overheating.

Another solution taken to solve this overheating in the common area has been the installation of a wood deck in the terrace, just in the corner where the south small façade and the big west façade joint each other. Two solutions can be applied here: The first of them is a wooden deck with inclined laths, which are installed according the inclination of the sun in the different periods of the year. In that way, the inclination of this laths will allow the sunlight goes through them in winter, but will stop this sunlight in summer and creating an additional shadow to this common area windows.

The second solution is a wooden structure, with a manually controlled horizontal curtain, that can be extended or collected depending on the owners' decision.

The system chosen is the first one, because will be more comfortable for the owners to not be worried about the sunlight and the curtain, and, if there is a period of time while anybody lives there, the solar screening is assured.

Once the additional shading objects have been decided, the shadings have been calculated again following Sbi-direction instructions, obtaining this shadows in BE10.

	Shading	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening
1	North Window 7	15	0	0	0	3,8
2	North Window 1	15	0	0	0	5,5
3	North Window 8	15	0	0	0	2
4	North Window 3	15	32	0	0	5,5

	Shading	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening
1	South small Window 1	15	62,7	77	0	5,5
2	South small Door	15	62,7	83	0	5,5
3	South small Window 2	15	83,2	79	0	5,5
4	South Window 6	15	0	0	0	8,3
5	South Door	15	0	0	0	5,5
6	South Window 5	18	0	0	0	8,3

	Shading	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening
1	East Window 1.1 (Laundry)	45	32	0	0	5,5
2	East Window 1.2 (Bedroom)	15	32	0	0	5,5
3	East Door	31	21,8	0	0	5,5
4	East Window 1.3 (Kitchen)	31	21,8	0	0	5,5
5	East Window 6	31	21,8	0	0	8,3

	Shading	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening
1	West Window 3	23	0	0	0	5,5
2	West Door (Kitchen)	15	67	0	59,5	5,5
3	West Window 1	15	67	0	73,85	5,5
4	West Window 2	15	84,7	0	69	5,5
5	West Door (B.1)	15	0	0	80	5,5
6	West Window 9 (B.1)	15	0	0	66	3,3
7	West Door (B.2)	15	0	0	50	5,5
8	West Window 9 (B.2)	15	0	0	42	3,3
9	West Window 5	15	0	0	34	8,3

Most heated room (only dwellings)

Floor area, m² 60 Calculate

Ventilation, l/s m²

Winter 0,32

Summer, day 1,2 night 0,9

Number of hours above

26 °C	27 °C
63	4

In BE10, the same values for windows than in the original project have been input, changing for the new one the U-values, areas and g-values. Once the shadings have also been changed, the overheating is checked again. In this case, the amount of hours above the limit temperatures are inside the acceptable ranges, so it can be said that the building fulfills the requirements for the overheating and thermal indoor climate.

Spain

In the case of this country and having seen the results of the daylight visualizer, can be expected that there will be overheating in the house. In Denmark is not a common practice to install blinds due to the less sunlight found there, however is the opposite here: in every time of the year there is enough sunlight, but in summer it also means a lot of heat going inside the house.

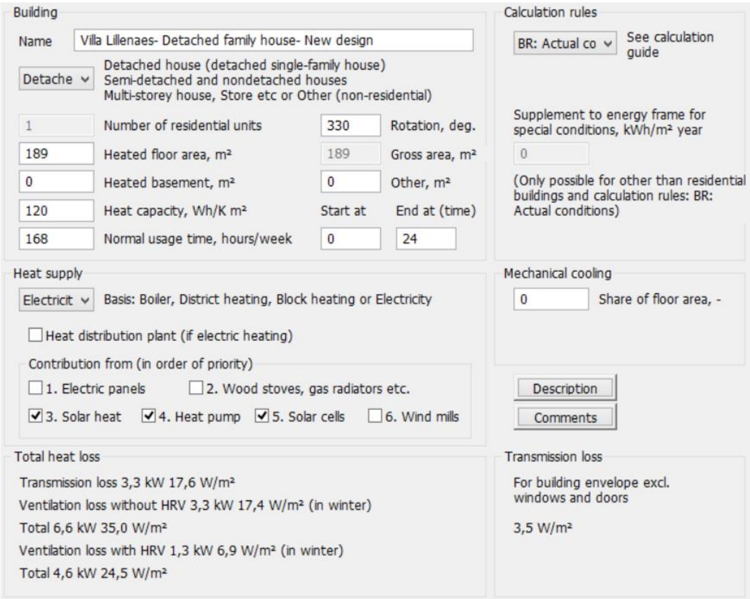
For this reasons the solutions taken to solve this overheating will be, as well, the installation of the wooden deck in the terrace and manual curtains in every window, but also blinds in each of them, to be able to manual control the amount of light and heat going through them.

Simulation with BE10

Different options have been proposed to improve the former result with BE10, but due to the process is the same, just examples of big changes are going to be explained here as well as the results.[23]

Initial information

The main changes in the table is that the heat is supplied with electricity instead of district heating. Below, the other energy sources are chosen in order of preference, in that case it is 1: Heat pump, 2: Solar heat, and 3: Solar cells.



The data the program calculates gives a total Transmission loss for building envelope elements of 3.5 W/m^2. In this case, BR2020 is fulfilled due to its limit value is 3.7 W/m^2, and the calculation gives a lower one.

Building envelope elements

All the changes that should be applied have already been explained in former points. For the external walls, roof and ground floor, the new areas and U-values are inserted, the same length of foundation is considered and some changes related the joints between windows and walls are applied.

Regarding windows and shadings, also new windows have been inserted and the shadings explained before are connected to this windows' table. With this data has been calculated the overheating.

The unheated room is remaining the same due to any changes, but ground floor U-value, have been applied.

[23] To see further calculations, see Annex B.5

Ventilation

The data of the new mechanical ventilation system is inserted in the table. While with the natural ventilation just two values where needed, here a deeper analysis should be done.

	Ventilation	Area (m	Fo, -	qm (l/s	n vgv (-)	ti (°C	El-H	qn (l/s n	qi,n (l/s	SEL (kJ	qm,s (l/	qn,s (l/s	qm,n (l/	qn,n (l/
	Zone	189		Winter			0/1	Winter	Winter		Summe	Summe	Night	Night
1	Mechanical vent. with	189	1	0,32	0,85	18	0	0,13	0	1	0,32	0,9	0	0

The area, usage time and airflow is the same than in the former calculation, but now, the efficiency of the ventilation unit as well as the temperature of the supplied air, and some infiltrations in winter, value given as an assumption by Sbi-direction. The Specific electricity consumption for air transport is limited in point 8 of BR10, with a value of 1000 J/m^3.

Domestic Hot Water

The main change in this part has been the installation of a different water tank, which technical information is given by the heat pump manufacturer. This tank has 180 l of capacity, and its heat loss is stated at 1.85 W/K.

Supply

This part includes the different renewable energy installations, and the analyzed ones are the solar heating plant, the heat pump and the solar cells, the three of them already explained in the part of Installations.

Results

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
61,2	0,0	61,2
Total energy requirement		26,7

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
35,3	0,0	35,3
Total energy requirement		26,7

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		19,2

Contribution to energy requirement		Net requirement	
Heat	0,0	Room heating	30,5
El. for operation of bulding	10,7	Domestic hot water	14,6
Excessive in rooms	0,0	Cooling	0,0

Selected electricity requirements	
Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	9,7
Ventilators	2,8
Pumps	0,5
Cooling	0,0
Total el. consumption	43,9

Heat loss from installations	
Room heating	0,0
Domestic hot water	1,5

Output from special sources	
Solar heat	6,9
Heat pump	38,2
Solar cells	2,6
Wind mills	0,0

The results table of the new proposal shows a much different result than the previous analysis. This time, the three energy performance frameworks for 2010, 2015 and 2020 are fulfilled.

Regarding the contribution to energy requirement, can be seen that just electricity is needed, and no extra energy should be applied for heating or for remove the excessive heat in the rooms. The amount of electricity needed by each system is shown in “Selected electricity requirements”.

The net requirement shows the amount of heat that should be applied to each system, while the table below it shows that there are heat loss just in the DHW system. The last table shows the amount of energy is produced by the renewable energy sources installed. From this table can be deduced that the installation of solar cells will be able to supply electricity just to the ventilation system, while the heat pump and the solar thermal collectors are able to supply the entire demand for both heating and DHW systems.

Comparison of results

From the results shown below it can be seen that, with the systems installed for each layout, the heat requirement has changed from a need of 80 to no need of extra heat supply, and the overheating problem have been solved. However, due to the installations works with electricity, this requirement has increased from the original project to the new, and the amount of electricity needed by each one is stated, showing the new implemented installations.

Due to the improvement on the building envelope elements and the implementation of a ventilation system, the building is more airtight and the net requirement for heat has decreased considerably for the new proposal. Also the heat loss for heating and DHW has been reduced.

For the renewable energies, the original project didn’t have extra production, and the values for the new installations are shown in the second one, with the amount of energy produced by each of them.

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
61,2	0,0	61,2
Total energy requirement		90,1

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
35,3	0,0	35,3
Total energy requirement		74,1

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		56,1

Contribution to energy requirement

Heat	80,0
El. for operation of bulding	2,7
Excessive in rooms	3,2

Net requirement

Room heating	59,4
Domestic hot water	18,0
Cooling	0,0

Selected electricity requirements

Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	0,0
Ventilators	0,0
Pumps	2,5
Cooling	0,0
Total el. consumption	33,4

Heat loss from installations

Room heating	2,6
Domestic hot water	4,9

Output from special sources

Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0

Key numbers, kWh/m² year

Energy frame in BR 2010

Without supplement	Supplement for special conditions	Total energy frame
61,2	0,0	61,2
Total energy requirement		26,7

Energy frame low energy buildings 2015

Without supplement	Supplement for special conditions	Total energy frame
35,3	0,0	35,3
Total energy requirement		26,7

Energy frame Buildings 2020

Without supplement	Supplement for special conditions	Total energy frame
20,0	0,0	20,0
Total energy requirement		19,2

Contribution to energy requirement

Heat	0,0
El. for operation of bulding	10,7
Excessive in rooms	0,0

Net requirement

Room heating	30,5
Domestic hot water	14,6
Cooling	0,0

Selected electricity requirements

Lighting	0,0
Heating of rooms	0,0
Heating of DHW	0,0
Heat pump	9,7
Ventilators	2,8
Pumps	0,5
Cooling	0,0
Total el. consumption	43,9

Heat loss from installations

Room heating	0,0
Domestic hot water	1,5

Output from special sources

Solar heat	6,9
Heat pump	38,2
Solar cells	2,6
Wind mills	0,0

Simulation with LIDER-CALENER

It was also an option to do a simulation with LIDER-CALENER, in order to see the energy behavior the house has in Spain.

However, a lot of problems with the program made impossible to have a good simulation and a good definition of the house, so at the end this option has been discarded.

But, ***which results were expected to be obtained?***

First of all, it was expected to have certified that the whole building fulfills the demands of the current legislation in Spain, and in second term, values about the energy expenses of the house.

Even without this simulation, it is possible to imagine that this results will be achieved. The reason to expect this is because the improved energy behavior has been achieved in a much colder country, but not only this, the legislation was made for 2020, so is more restrictive than CTE2013, and even though it fulfills the energy requirements.

About if the Spanish legislation is fulfilled, can be expected so due to the analysis made in former points, comparing the solutions taken with the Spanish regulations, and everything was inside the limits required.

Budget[24]

Denmark

To be able to know the approximate price the total construction will cost, the prices have been searched in Sigma prices' database, which is used by Constructive architects to develop their budgets, so it is possible expect to find there realistic prices. However, not all the constructive elements it have been chosen can be found, for that reason, the most similar constructive elements have been taken in these cases, and some of the others have been taken material by material to make an approximation. Furthermore, there are prices that are not exact even in the database, and the price shown there is stated as an average value per square meter.

The budget includes the prices of the materials and components, but also includes the cost of installation or construction. After calculating the total amount of money, an average percentage of contribution margin and the VAT have been added, taken normal values for this type of project.[25]

	Unit	Quantity	Unit cost	Cost
Building substructure				
Superficial excavation, 400mm with dozer	m^2	118	4,5	531
Basement excavation and moving	m^3	47	49	2.303
Foundations of concrete, t=410mm, h=1.1m	m^3	31	1.521	47.151
Terrain slab				
Screed	m^2	230	51	11.730
Polystyrene	m^2	230	888,5	204.355
Structure (Average price for a single family house)	u	1	763	763
				266.833

[24] All the prices are shown in Danish Krones (dkk)

[25] The information used to develop this Budget has been found in projects and help documents provided by teachers from Construction Management.

	Unit	Quantity	Unit cost	Cost
Primary building components				
Outer walls				
Basement walls				
Concrete	m^3	43	1.453	62.479
Water rough plastering	m^2	102	100	10.200
External walls				
Concrete	m^2	180	1.073	193.140
Mineral wool	m^2	180	126	22.680
Tiles	m^2	180	816	146.880
Internal walls	m^2	131,4	643	84.490,2
Prefabricated concrete stairs				
Steps	u	24	1.413	33.912
Roof, 20º slope, U-value = 0.1 m^2/K				
Timber structure	m^2	201,5	149	30.023,5
Mineral wool	m^2	201,5	95	19.142,5
Tiles	m^2	201,5	241	48.561,5
				651.508,7

	Unit	Quantity	Unit cost	Cost
Carpentry				
Outer walls				
Front door	u	6	12.837,5	77.025
Garage door	u	2	14.750	29.500
Electrical operation	u	2	10.432	20.864
Windows, triple glazed, aluminum frame				
W1	u	10	6.808,5	68.085
W2	u	6	2.671,5	16.029
W3	u	6	5.231	31.386
W5	u	3	4.460	13.380
W6	u	2	4.427,5	8.855
W7	u	1	4.460	4.460
W8	u	1	7.180	7.180
W9	u	2	7.180	14.360
Internal doors				
Single flush solid door	u	6	3.987,5	23.925
Wet room door	u	1	4.397	4.397
Sliding door	u	2	4.339	8.678
				328.124

	Unit	Quantity	Unit cost	Cost
HAVC systems				
Sanitation				
Wahsbasin	u	2	4.273	8.546
Toilet	u	2	4.846	9.692
Sink	u	2	5.750	11.500
Shower	u	2	11.388	22.776
Hot water tank	u	1	17.325	17.325
Heating				
Heat pump	u	1	69.000	69.000
Floor heating	m^2	189	260	49.140
Solar collectors	u	2	32.416,5	64.833
Ventilation (Average price for a single family house)	m^2	189	42	7.938
				260.750
Electrical system				
Solar cells	u	4	27.150,5	**108.602**
Furniture (Average price for a single family house)	m^2	189	474,5	**89.680,5**
Building site				
Running site				
Telescopic lift	month	12	13.500	162.000
Sanitary cabin	month	12	2.500	30.000
Foreman's cabin	month	12	1.250	15.000
Sheds cabin	month	12	1.250	15.000
Material container	month	12	600	7.200
Set up/down site				
Set up cabins	u	1	3.000	3.000
Pick down cabins	u	1	3.000	3.000
Electrical installations	days	240	99	23.760
Lights	month	12	200	2.400
Water	month	12	200	2.400
Telephone	month	12	250	3.000
Fences	days	240	1.538	369.120
				635.880

SUMMARY	Cost
Building substructure	266.833
Primary building components	651.508,7
Carpentry	328.124
HVAC systems	260.750
Electrical system	108.602
Furniture	89.680,5
Building site	635.880
	2.341.378,2
Contribution margin: **15%**	**351.206,7**
VAT: **25%**	**585.344,6**
TOTAL	**3.277.929,5 dkk**

To be able to compare both prices, the amount taken for that will be the price obtained before taxes, 2.341.378,2 dkk. But also is needed to have this price in the same currency, so taken into account that 1€ = 7,45 dkk, at the end is obtained a price of **313.860,78 €.**

Spain

In order to know the price the construction of the house will cost, the program CYPE and it budget generator has been used, with the prices database for the Valencian Community. The next picture shows the summary table[26] of each chapter in the budget and the final price before taxes, in order to compare it with the Danish budget.

[26] The entire Budget with its descriptions of each part can be found in Annex D. Budget

PRESUPUESTO DE EJECUCIÓN MATERIAL

PRESUPUESTO DE EJECUCIÓN MATERIAL		
Nº	**CAPÍTULO**	**IMPORTE (€)**
1	ACONDICIONAMIENTO DEL TERRENO	**14.284,33**
2	CIMENTACIONES	**18.023,79**
3	ESTRUCTURAS	**50.190,13**
4	FACHADAS	**52.960,21**
5	GESTIÓN DE RESIDUOS	**5.200,28**
6	INSTALACIONES	**23.555,82**
7	AISLAMIENTOS E IMPERMEABILIZACIONES	**8.591,68**
8	PARTICIONES	**11.404,80**
9	CUBIERTAS	**18.984,06**
10	REVESTIMIENTOS	**23.629,52**
11	SEÑALIZACIÓN Y EQUIPAMIENTO	**5.921,75**
12	URBANIZACIÓN INTERIOR DE LA PARCELA	**61.184,19**
13	CONTROL DE CALIDAD Y ENSAYOS	**637,84**
14	SEGURIDAD Y SALUD	**9.999,83**
Presupuesto de ejecución material		**304.568,23**

Asciende el Presupuesto de ejecución material a la expresada cantidad de TRESCIENTOS CUATRO MIL QUINIENTOS SESENTA Y OCHO EUROS CON VEINTITRES CÉNTIMOS

As can be seen in the summary table, the total price before taxes is of **304.568,23 €,** and comparing it with the one obtained with the Danish prices, **313.860,78 €**, can be conclude that the Spanish price is around 9.000€ cheaper.

6. CONCLUSIONS

For this project, the building energy behavior has been compared with the current Danish building regulations, but trying to improve the consumption of it, it has been taken into account the possibility of reaching the values required for the energy performance frameworks for 2015 and 2020.

The values that will show if the building is actually low consumer of energy are the energy performance framework and the design transmission loss through building envelope elements.

In order to consider the building as a low energy consumption house, at least 2015 values need to be reached, and additionally will be try to arrive to 2020. The values are the following ones:

LEGISLATION	ENERGY PERFORMANCE FRAMEWORK (kWh / m^2 year)	DESIGN TRANSMISSION LOSS (W/ m^2)
BR08	81.64	6
BR10	61.23	5
BR2015	35.29	4
BR2020	20	3.7

Due to the project was made in 2008, it can be expected, even before of doing a simulation, that this energy parameters are not going to be achieved, also is possible that other minimums, like U-values, are not fulfilled. For that is known that some changes in the constructive elements will be need to be made to improve the energy behavior of the building. But also will be kept in mind the price of the solutions proposed.

It has been decided that the indoor environment of the building will be analyzed and some installations like a mechanical ventilation system and some renewable energy sources will be installed, in order to reduce the total energy consumption.

To know how much consumption the original building is using, and be able to know which elements need to be improved, some simulation programs have been used.

A first simulation with BE10, program that analyze Danish building regulations, have been made, and due to the final results obtained it can be concluded that the building envelope should be improved and lower in this way the design transmission loss. Doing that, the heating requirement will be also lower due to the airtightness of the building (the more airtight, the less heat losses), so this will mean a lower energy requirement for heating. This first analysis also showed the thermal indoor environment with the overheating calculation, showing that the time above the limit was exceeded in a large way, so solutions like adding shadings to the windows or installing a wood deck in the terrace have been considered.

Another simulation, this time with VELUX daylight visualizer has been made to calculate the daylight factor in each room. With this analysis could be seen that more daylight was needed. This was a challenge due to, on the one hand, to increase the daylight factor should be increased the glazing area, but on the other hand, doing this could increase even more the problem of overheating.

This is one of the reasons of installing a mechanical ventilation system. Apart of improving the atmospheric indoor climate, it can also help to control the indoor temperatures, so this overheating, together with the new shadings, is reduced. The installation has been calculated, so the airflows, dimension of diffusers and ducts and a ventilation unit have been installed. To dimension the diffusers, DIMcomfort dimensioning program have been used. Also some plans and drawings have been made, showing the installation to make it more understandable.

Also it has been decided to implement renewable energies in the house, to produce enough energy to supply the installations like ventilation, floor heating and domestic hot water. This additional installations are a heat pump and thermal solar collectors, which are used to warm up the water tank that supplies DHW and floor heating. On the other hand, some solar cells have been installed and they produce some of the energy needed by the ventilation system.

In order to know if the improvements are good enough, a second simulation with BE10 has been calculated. With the new U-values, new shadings and technical data for the installations, the final results show an important decrease of the design transmission loss, as well as a decrease in the heat requirement. The values show that not only 2015 values are achieved, but also 2020. So can be concluded that the purpose of the project have been achieved and the building can be considered a low energy consumption house.

Apart from the energy analysis, a budget has been made. It is important to mention that the prices found, even extracted from a reliable source as is a database used by Constructive architects, are approximated prices, and some of them should be considered average prices for single family houses. The price of each constructive element proposed to improve the building envelope has been considered, but in this case, the need of reducing the amount of energy consumed has been higher that the need of lowering the final price of the construction. With the improvements implemented it has been possible to reach the purpose of the project.

But after making all this improvements considering the house is placed in Denmark, the possibility of placing it in Spain have been also considered, so all this new proposals have been compared with the Spanish legislation, first of all, to see if they fulfills Spanish legislations, and in second term, to know the energy behavior this house will have in another country.

The changes proposed to improve the building envelope have been checked and compared with the minimums the legislation requires, and all of them are inside this minimums, but not only fulfilling them, also with a huge improvement. This is due to the Spanish legislation is of 2013, and all the changes implemented where thought to fulfill requirements for 2020.

In the case of the installations there are some differences between both countries also. For the Danish case, the Domestic Hot Water and floor heating are supplied by a heat pump and some thermal solar panels. Even just the heat pump has been dimensioned to fulfill by its own the total demand, the thermal solar panels have in installed as a support installation. This has been thought in this way due to with this two renewable energy installations, the house is completely disconnected from the grid, and in case one of them fails, the other will be able to supply this demand until the broken one is fixed.

In Spain this will be different. The main renewable energy supplying the demand of DHW are the thermal solar panels, which are able to supply by their own the total demand. This has been done in this way because the price of the electricity, the main source of energy a heat pump uses to work, is more expensive here, and also it has not been produced in a renewable way. In the case something happen to the installation, until it will be fixed the DHW tank can work for some time with electrical resistances that warm up the water to supply this demand.

Another renewable energy thought has been the photovoltaic panels. After studying how many will be needed, it has been concluded that a number of 36 panels are needed. Making a rough budget of them, the price for this amount of panels is around 7.000€. This amount of panels are needed due to it's not allowed to make some electricity at home and be connected to the grid at the same time, so they are necessary to supply the whole electrical demand. Due to the price they have, the decision of install them or not will be taken by the owners of the house, who will need to consider if this cost is affordable by them and also if it's worthy.

About the indoor environment, the atmospheric indoor climate and thermal indoor climate have had the same considerations like the Danish case, so with the installation of the ventilation system they have been improved. However, the case of the visual indoor climate is different comparing both cases: while in the Danish legislation there is a minimum to be reached referring the Daylight Factor, there is no minimum in the Spanish case. This is understandable due to the position of the countries and the amount of sunlight they have. In Denmark, there are few hours of sunlight in winter, and even in summer they double this amount of time, the need of taking as much profit as it's possible of this sunlight in winter time make this minimum Daylight Factor to have sense. Is for this reason the Danes don't build the houses with blinds and few of them have curtains in front of the big windows.

However, this considerations are very different in Spain. There is a small difference on the amount of sunlight hours the country has between winter time and summer time, so there is no need of taking as much profit as it's possible. In fact, this sunlight is going together with a lot of heat going through the windows, and is for that reason is common in Spain to have blinds and curtains in every window to control manually the amount of heat going inside the houses. But also the light should be controlled, as could be seen in the Daylight visualizer simulations, because of an 8% of Daylight factor could be even uncomfortable.

In the case of budgets, at the end have been seen that there is not as huge difference between them as could be thought. In fact, the difference is of 9.000€ less in Spain than in Denmark, comparing the budgets before taxes. This amount of money that can be saved could be used for the PV panels' installation, which will be amortized in around 7 years and allowing the owners to have savings after this time.

7. PERSONAL REFLEXION

While doing this project, I've seen a lot of data and numbers referring to energy, energy savings, energy used by the houses and its installations, money expended…

All this data have made me realize the direct impact the way of constructing houses have in the climate change, and also, the direct impact we, as Technical Architects, can have to solve this.

When I see the different results obtained between constructing a house as usual and thinking about energy savings, I feel is our responsibility to change our minds and to make all we have in our hands to improve the situation we are living nowadays, and decrease as much as we can the energy expended by all the houses made and the ones that will be made in a future.

Is not impossible to achieve this goals, and when all this new technologies will improve, can be expected that their price will decrease and will be easier to implement all renewable energies and new ways to build houses in an efficient way, without having a big impact in the budgets.

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